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WOODWORKING MACHINES AND EQUIPMENT PRODUCED IN YUGOSLAVIA*

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1. INTRODUCTION

In the period between World War I and World War II woodworking machines and equipment were manufactured, in Central Europe, only in Germany and Czechoslovakia. In the territory of the present Socialist Republic of Slovenia, however, this type of equipment had already been manufactured by the Gustav Tines Company. This company had manufactured more than 70 different types of machines - from gang and frame saws to tool-sharpening machines. Later on, the company went bankrupt and, for a very long period of time, it was not substituted by a firm of a similar type. In the period from 1960 to 1970 the first partial production lines that included a number of linked technological operations appeared on the European market; at the same time the first woodworking machine manufacturing plants were established in Yugoslavia based on the former workshops. At the present time there are 35 small and large manufacturers in Yugoslavia whose annual output is about 6,000 to 7,000 tons of woodworking equipment, which accounts for some 20 per cent of Yugoslavia's total requirements in this field. The balance of machines and equipment needed must, therefore, be imported. Within the present framework of economic recession an ever increasing number of woodworking plants have been developing their own manufacturing lines for individual machines in their existing repair shops. Possibilities of co-operation in the field of the manufacturing of special machines for woodworking industries are at present being considered in Yugoslavia; only in this manner is it possible to bridge the gap in the levels of development between the West and our country in this specific production field. All companies of this type in Yugoslavia are members of their business association, similar to that of West German manufacturers (VDMA) or the one in Italy (ACIMALL).

PRODUCTION OF WOODWORKING MACHINES IN YUGOSLAVIA (IN TONS)

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Yugoslavia	1742	1877	1764	1553	2960	2641	3358	3529	5224	7727
Bosnia/H									65	52
Croatia	926	906	883	808	2092	1086	1338	1313	2052	3052
Slovenia	247	322	224	197	168	163	336	224	1297	1329
Serbia	569	649	657	548	700	1392	1684	1992	1810	3294

NUMBER OF MANUFACTURERS

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Yugoslavia	n.a.	n.a.	6	6	6	6	n.a.	7	9	9
Slovenia	n.a.	n.a.	3	4	4	4	n.a.	5	5	5
Croatia	n.a.	n.a.	2	1	1	1	n.a.	1	2	2
Serbia	n.a.	n.a.	1	1	1	1	n.a.	1	1	1

The production of the 35 manufacturers existing in 1984 may be classified as follows:

1. Production of basic machines
2. Production of bandsaws and sawmilling machines
3. Production of wood-drying machines
4. Production of transportation equipment
5. Production of varnish drying lines
6. Production of packaging machines
7. Production of exhausting devices
8. Production of power units for solid fuel and/or woodworking industry wastes.

The production of basic machines may further be classified as follows:

1. Saws
2. Sanding machines
3. Spindle moulders
4. Tenoners
5. Planing machines
6. Multi-edge profiling machines
7. Hydraulic and pneumatic presses
8. Other machines

2. SAWS

(a) Saws for angular sawing or a combination of a table circular saw

These machines are basically used as portable saws in construction sites and for purposes of finishing works and interior decoration in buildings. Using this type of saw wood pieces can be sawn at any angle; they can, on the other hand, also be adjusted to serve as table circular saws. The blade diameter may go up to a maximum of 300 mm, and the engine power is 1.5 kw.

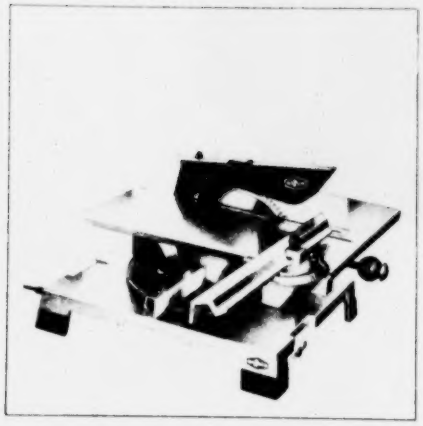


Figure 1. Saw under table, sawing as a table circular saw.

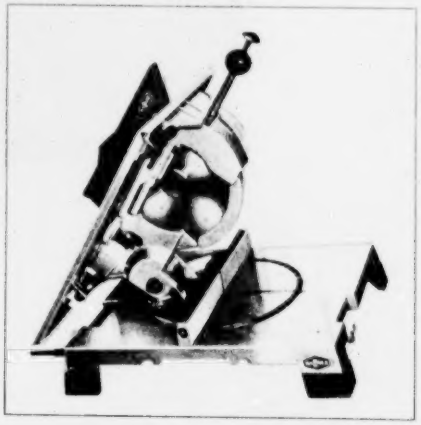


Figure 2. Table and saw lifted for sawing as a radial arm cross-cut saw.

(b) Circular table saws for cutting to size

This machine is supplied with a pre-cutter, which allows the high quality cutting to dimension of boards; this is particularly significant when cutting boards surfaced with a melamine or another type of foil. The main axle may be set for three different RPMs: 4,000 to 6,000. The saw blade may be inclined at an angle of up to 45^{o}, hence the possibility of angular edge cutting. This is a standard woodworking machine suitable for furniture and production of solid wood products.

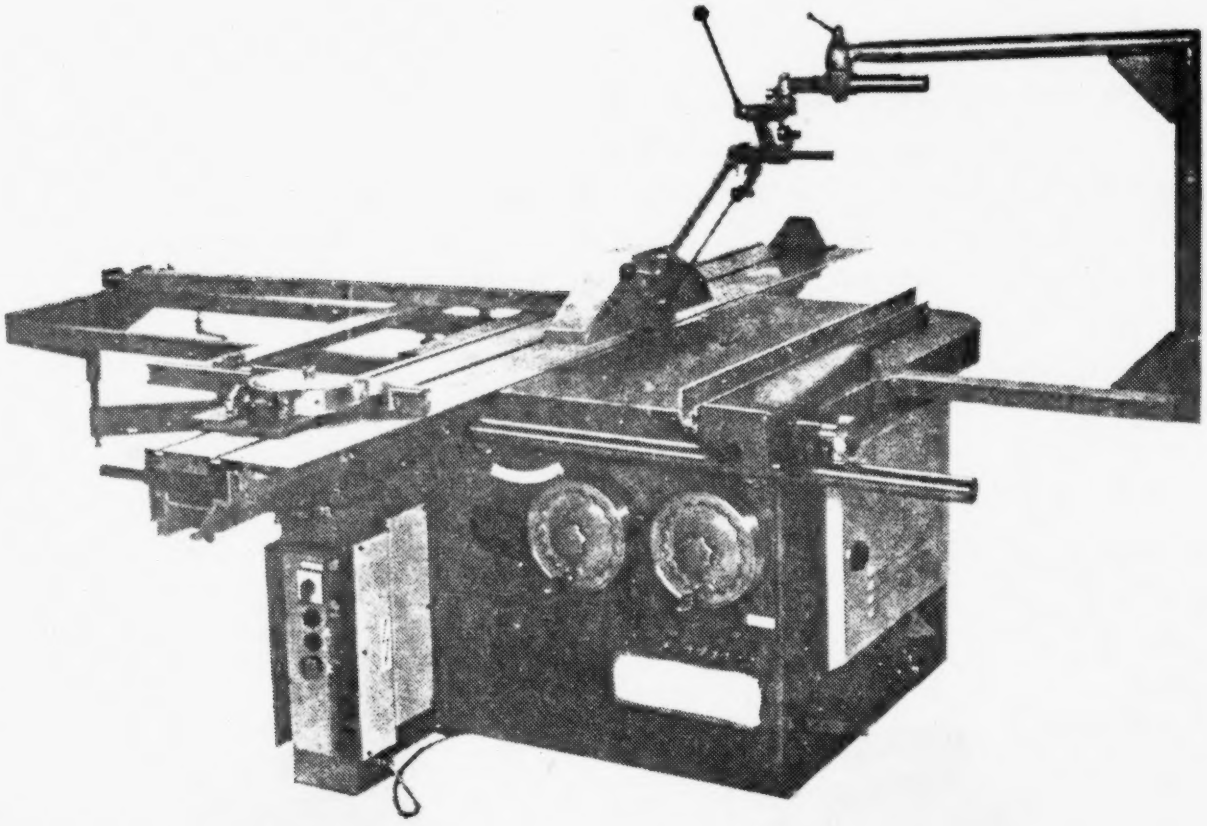


Figure 3.

(c) Circular saws for cutting to size (with manual setting)

The saw may be supplied with a pre-cutter for high precision sawing of surface improved boards. The maximum working width is 2,500 mm and the minimum is 250 mm. The power of the engine is 4.5 kw and that of pre-cutters 2.2 kw.

This saw can be utilized for the sawing of solid wood or boards.

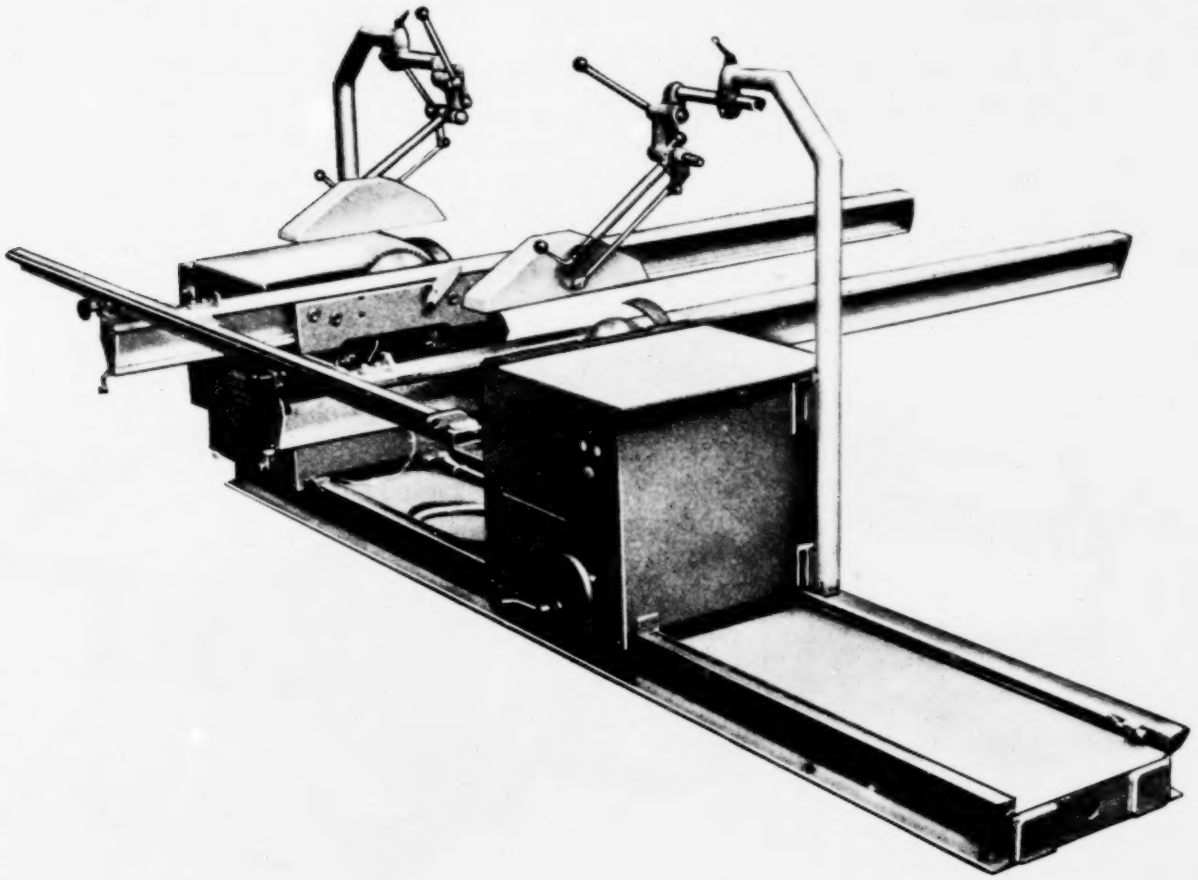


Figure 4.

(d) A combined woodworking machine

This machine can perform 5 different operations, namely:

- planing
- sawing
- moulding
- tenoning
- thickness planing to a predetermined thickness

Planing widths range between 410 and 610 mm and thicknesses from 5 to 190 mm. The cutter operates at 4 different RPMs, the maximum being 8,000 RPM.

This machine is exclusively used for individual tailor-made production lines and/or workshops for prototypes.

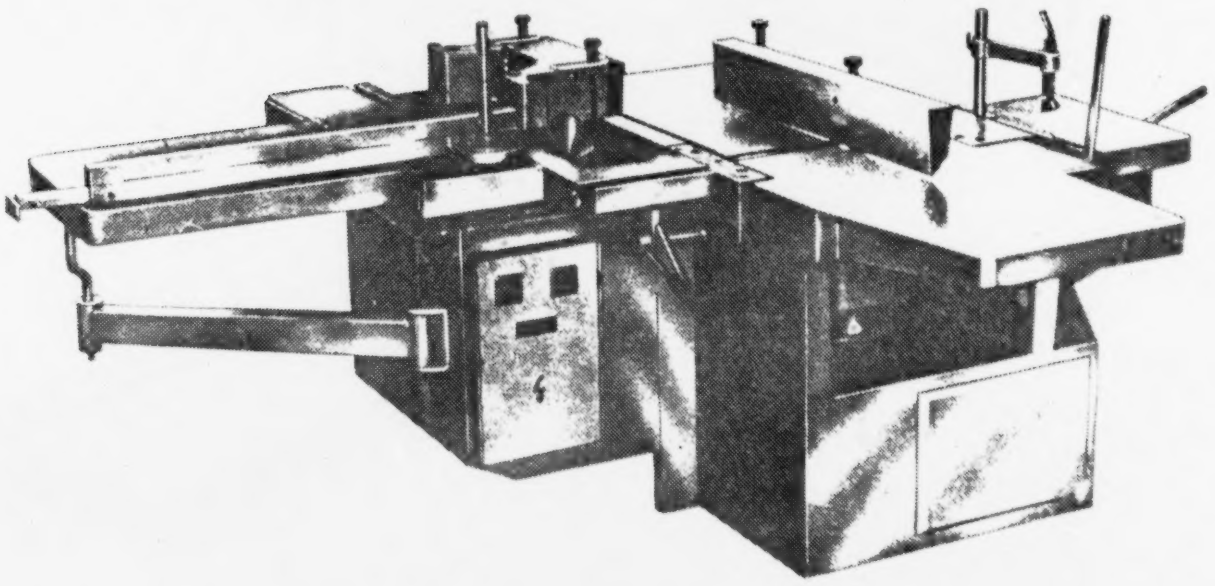


Figure 5.

(e) Vertical saw for cutting to size

This saw is available either as an automatic or a manual machine. Dimensions of this saw are 6,900 x 2,650 mm, and the machine is particularly designed for the cutting of large-size particle boards or other types of boards. It is not supplied with a scribing blade; therefore it is suitable for initial rough sawing only.

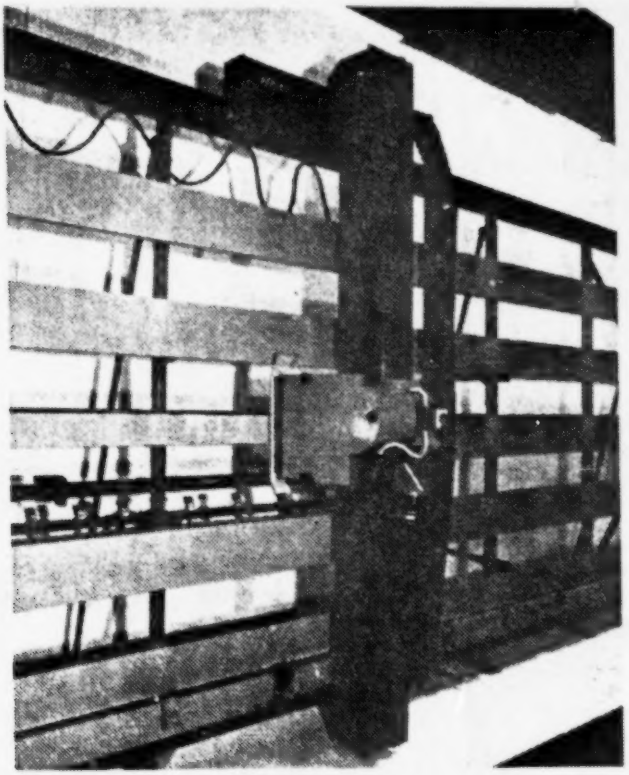


Figure 6.

(f) Double automatic circular saw for cutting to size

This is the largest among saws and/or moulding machines manufactured in Yugoslavia; it is used for automatic cutting to size and profiling of edges in a continuous process. Two saws of this kind may be combined into an angular or straight production line, which allows the processing of all 4 edges of a board without any need of idle movements. The machine

is usually supplied with 4 units on each side (pre-cutter, crusher, the first cutter and the second cutter). Maximum working width is 3,000 mm and minimum width is 176 mm. If it is necessary to achieve fine processing, the cutters' RPM may be as high as 7,000. This is feasible through the use of a high-frequency converter, whereas their usual RPM is 3,000. The units mentioned above can also operate at a certain angle.

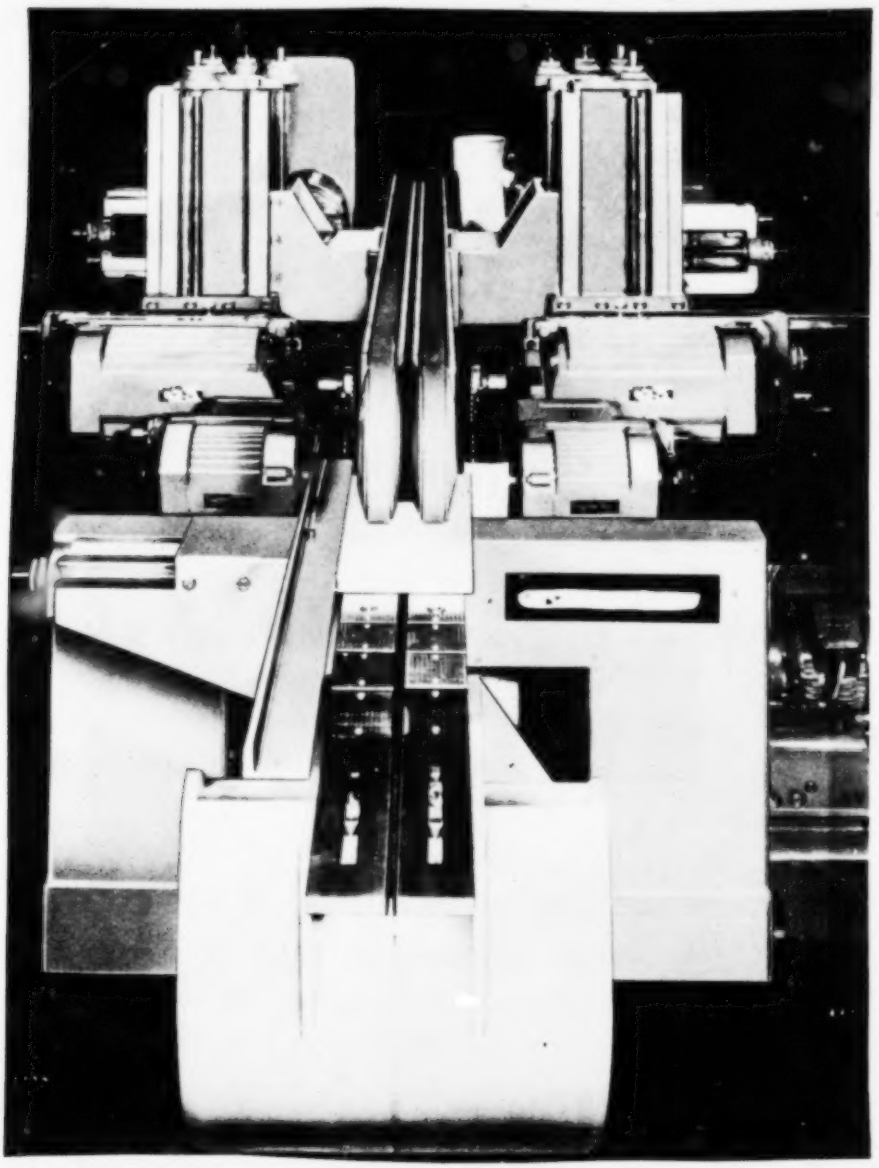


Figure 7.

(g) Portable hand saws

In addition to fixed saws Yugoslav enterprises also manufacture manual woodworking machines and equipment; they perform operations equal to those of the fixed machines, yet they are only used for manual woodworking processes. The Yugoslav industry of woodworking machiens and equipment manufactures electric saws, planing machines, tenoners, sanding tools, cutters, etc. These are produced partially on the basis of domestic know-how, and to a certain extent on the basis of co-operation with foreign partners.

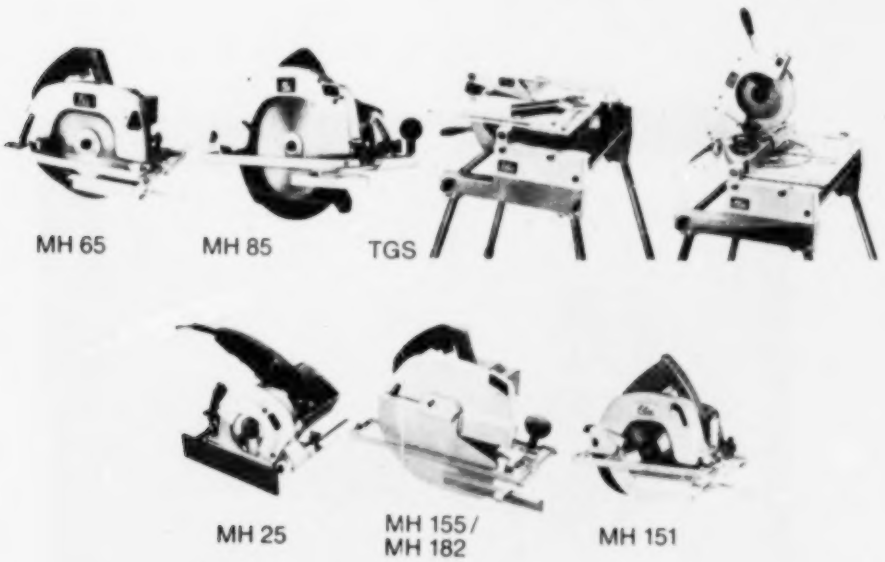


Figure 8.
Portable electric circular hand saws.

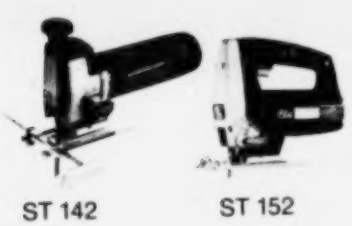


Figure 9.
Portable electric fret saws.

3. SANDING MACHINES

Apart from the usual band sanding machines the wide-bolt sanding machines with one or more operating units are also manufactured on the basis of co-operation with foreign partners. Working widths of these machines range between 600 and 1,300 mm. The following combinations are available: roller-cushion, roller-roller or cushion-cushion. The machines are suitable both for the levelling of boards and edge sanding of veneer-coated surfaces. Thickness regulation may be monitored electronically.

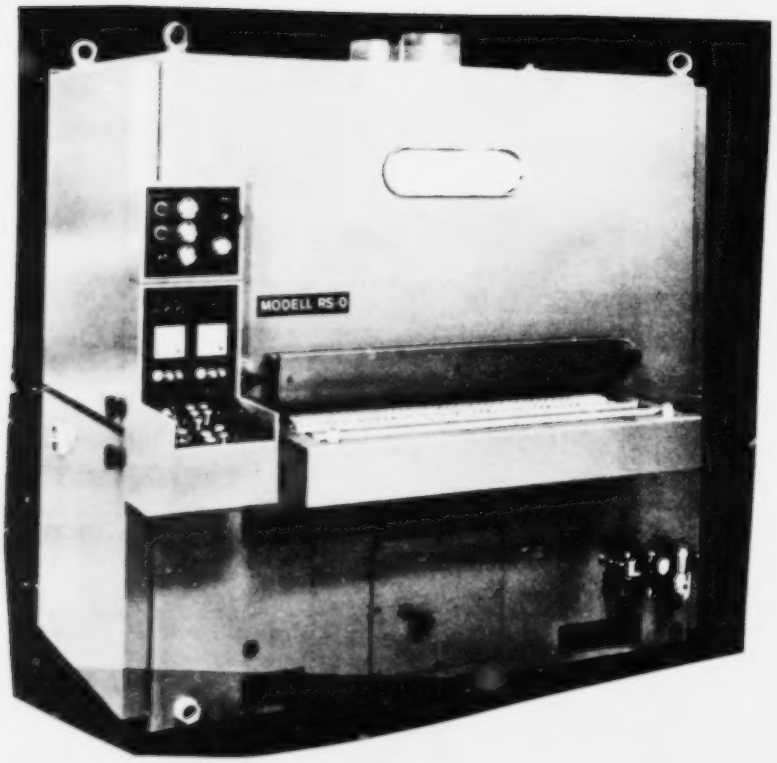


Figure 10.

4. SPINDLE MOULDERS

(a) Table spindle moulders are manufactured in varying designs and different RPMs of the main operating axle, which all depends on the type and quality of wood. Maximum number of revolutions per minute is 18,000. This type of machine is used mostly in the production of windows and doors.

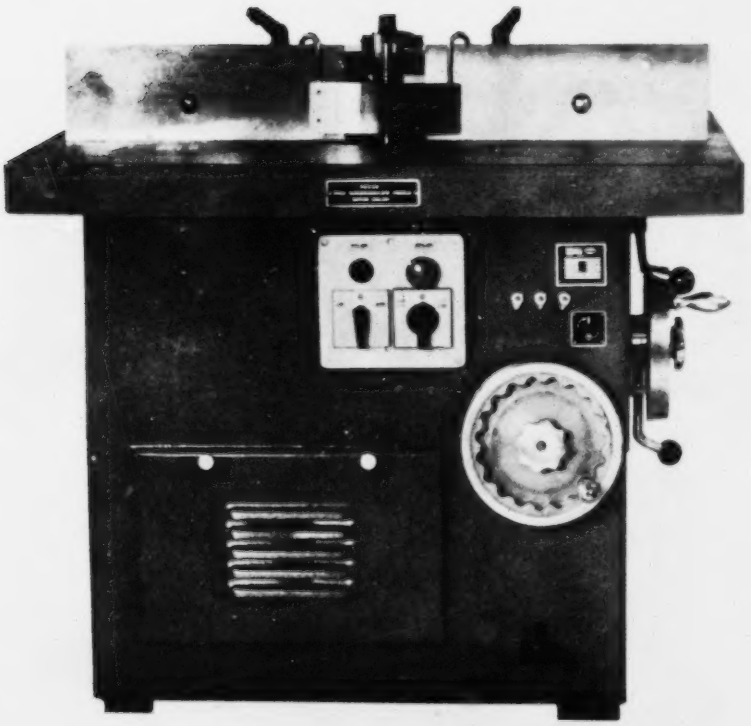


Figure 11.

(b) Routers

Machines of this type are produced in different designs in terms of:

- revolutions per minute
- method of operating the unit's lift
- number of cutting heads

Usually the number of revolutions per minute is 12,000/18,000, and the spindle may be lifted either pneumatically or mechanically.

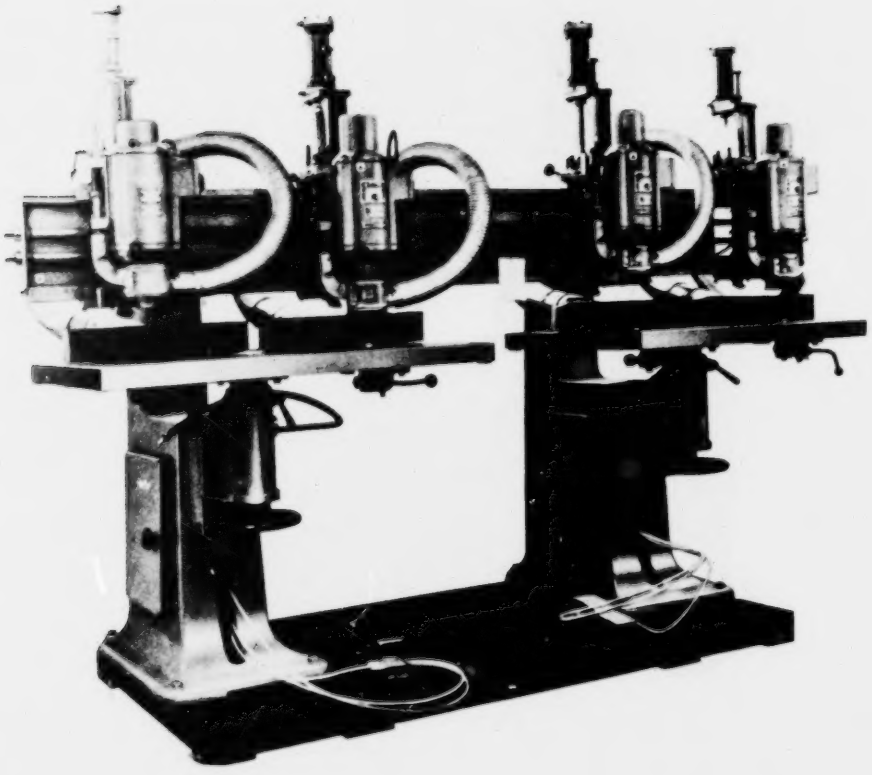


Figure 12.

(c) Oscillating boring and mortising machines

These 2 machines are indispensable primarily in the manufacturing of chairs; in Yugoslavia production of these machines was introduced a long time ago, and they are required to make notches and tenons for connecting elements in individual types of chairs.

The maximum boring depth that an oscillating mortising machine may reach is 100 mm, the number of oscillations being 200 per minute, and axle revolutions up to 1,000 per minute.

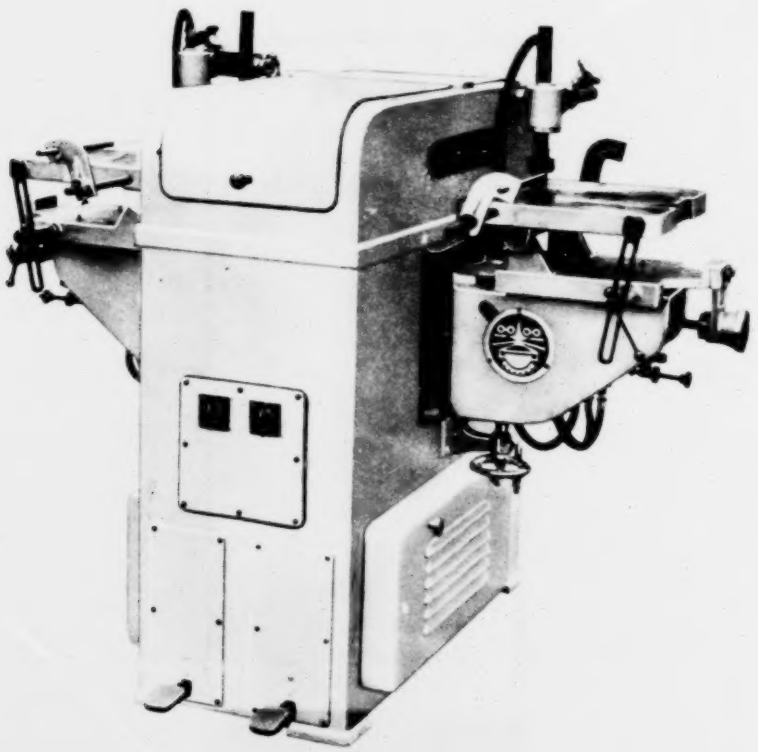


Figure 13.

5. MULTI-HEAD BORING MACHINES

(a) Electro-pneumatic multi-head boring units with a pneumatic lift

Through the manufacture of machines of this kind the woodworking industry, particularly that of solid wood furniture, has been provided with an opportunity to adjust the machine to its specific needs. One machine may be supplied with more than one (up to 16) horizontal and vertical boring units that may operate at the same time. The units may also be inclined at different angles thus allowing not only vertical but also angular bore-holes. The boring heads are supplied with one or more spindles.

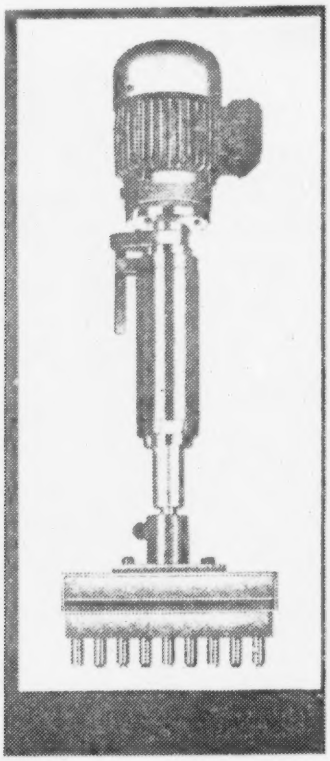


Figure 14.

(b) Dowel boring machines

The figure below shows a small machine with a horizontal and a vertical operating unit for boring dowel holes that are required in the manufacturing of casegoods. The machine has a pneumatic locking device and 20 spindle heads; the distance between individual spindles is 32 mm thus complying with an international standard. Yugoslav enterprises also produce dowelling machines with a number of operating units located at the bottom and used for vertical operation, and others located at the machine's sides that are used for horizontal boring; the units operate on a continuous basis and may be monitored electronically. To boost the quality of boring and clean the bore-holes the spindles of the horizontal operating units (heads) operate at 6,000 revolutions per minute, and those located on the vertical heads at 3,000 RPM.

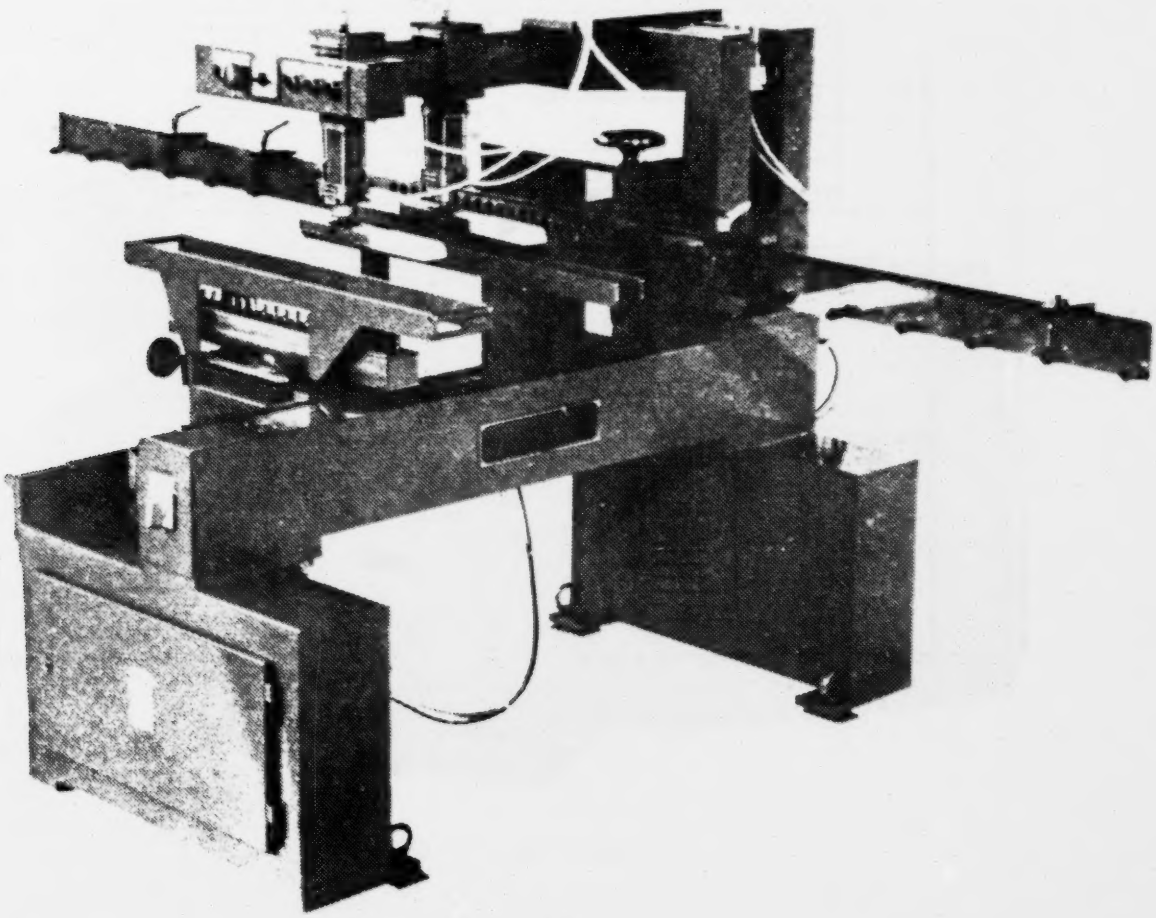


Figure 15.

6. WOODWORKING LATHES

In this field our manufacturers have only recently embarked upon their own production. Tests have been made with a lathe for circular elements, operating either manually or automatically.

The maximum diameter of the elements is 75 mm, and maximum length 750 mm. The capacity of the machine is about 3,600 pieces per hour for small pieces.

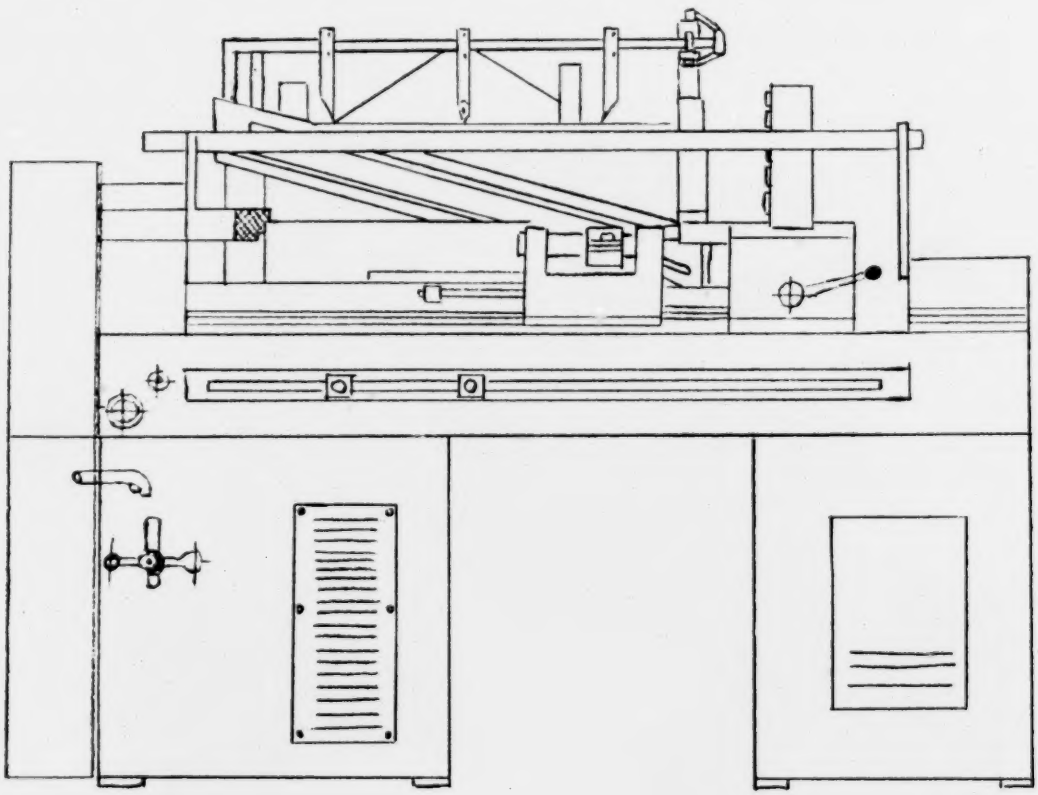


Figure 16.

7. 4-SIDE PLANING MACHINES

These machines are furnished with vertical operating units used for profiling, and horizontal units used for planing, either from the top or from the bottom. When necessary the machines can also be supplied with a guide, located on the table; it is thus possible to lead short elements of hardwood very accurately through the machine. When leaving the machines all 4 sides of the elements are machined (profiled). A four-side planing machine with a conveyor can be coupled to a double end tenoning machine. In a continuous process elements may thus be processed in both the longitudinal and transverse directions. When required, an automatic stacker can also be added at the end of this partial production line.

Partial production lines for the manufacturing of parquet fingers operate on the basis of a similar process.

Four-side planing machines can plane planks that are up to 170 to 220 mm wide, and the number of their machining heads ranges from 4 to 9.

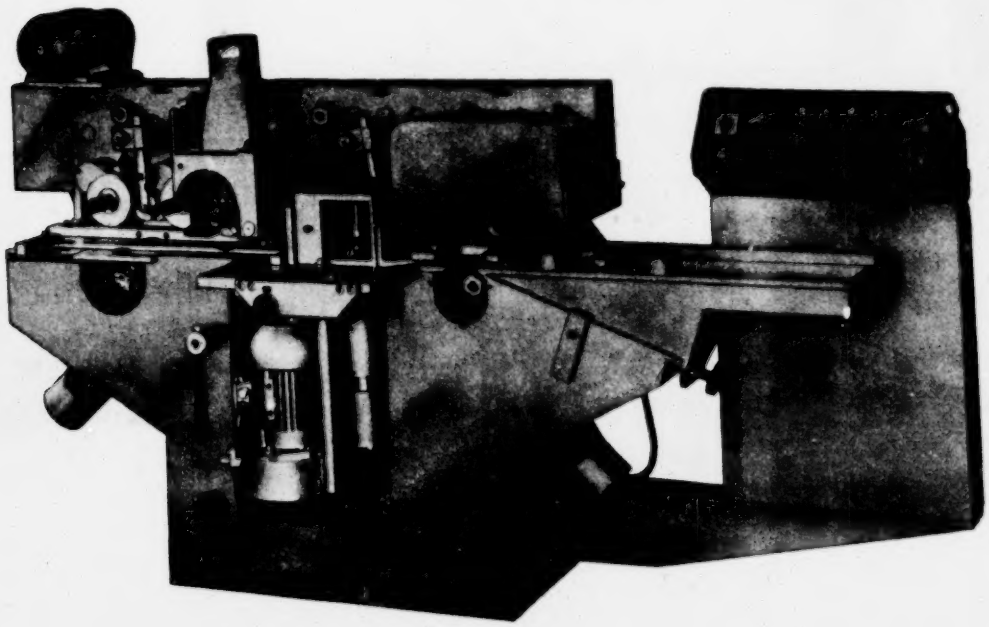


Figure 17.

8. HYDRAULIC AND PNEUMATIC HOT PRESSES

(a) Flat woodworking presses

These hot presses are designed either with electrical or steam heating of platens. They have one or more daylights into which elements can be inserted manually. Pressure monitoring is performed by a manometer and temperature control and regulation by thermostats that have a special clock mechanism built in, which allows one to set effective pressing time that depends on the type of glue and the gluing temperature required. Specific pressures at which the press operates range between 2 and 5 kp/cm^2.

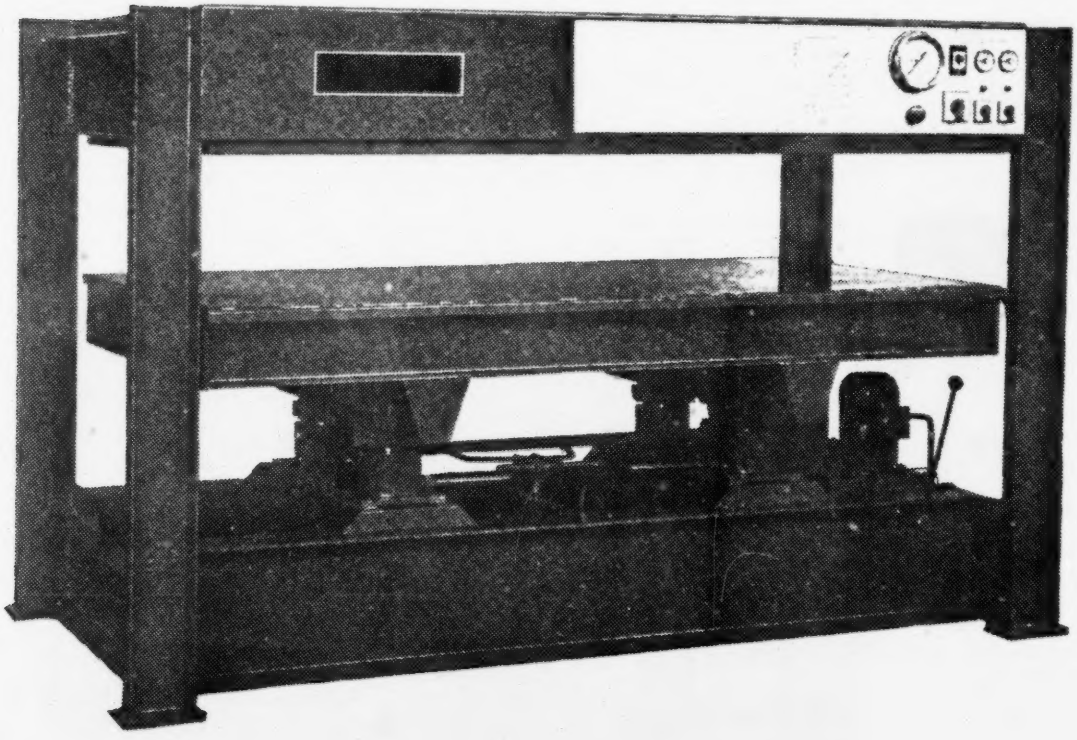


Figure 18.

(b) Form presses

These presses are primarily used for production of plywood required for pressed elements, such as chair seats and back-supports. The heating may be by steam, hot water or high-frequency electric current. The forms used with this press are made either of a light metal or wood. The pressure required for the operation of these presses is higher than that of woodworking presses, and may go up to 20 kp/cm^2.

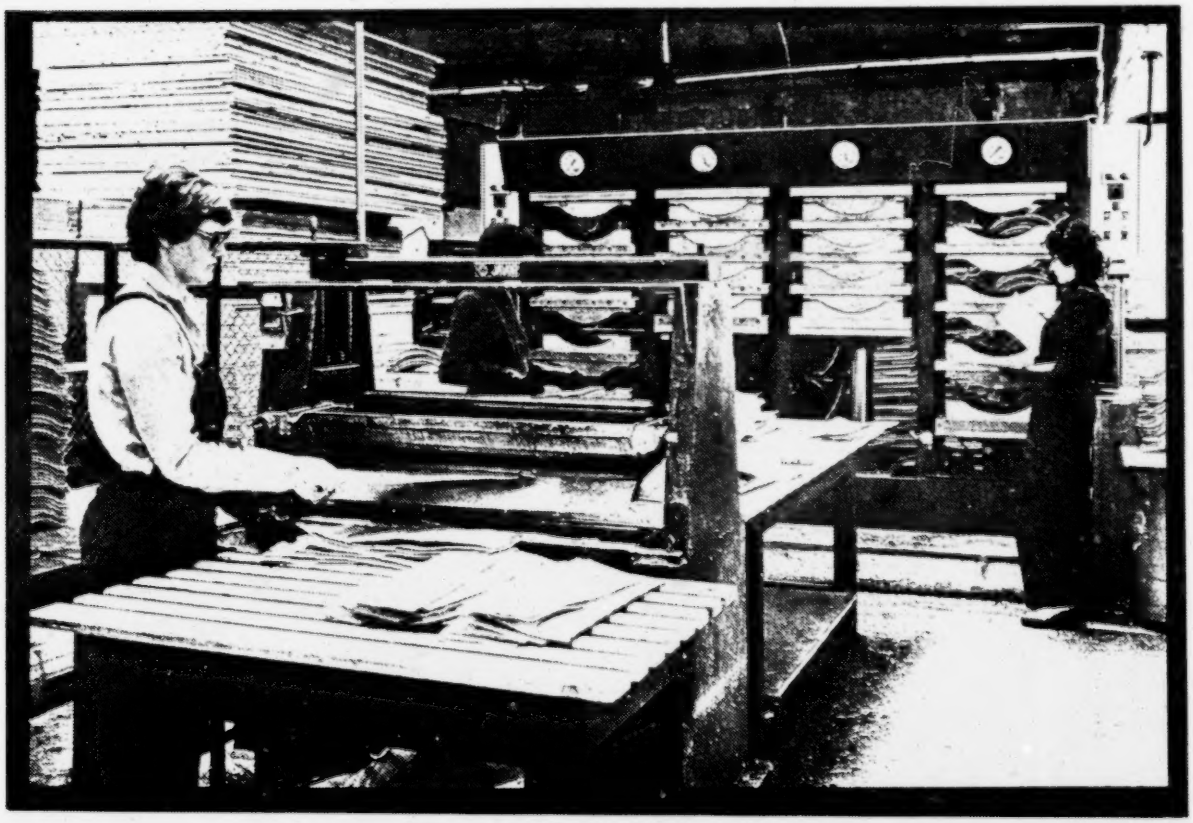


Figure 19.

(c) Rotating clamping presses

Presses of this type are mostly used in the manufacturing of solid-wood seats for chairs where round-edge gluing is required. In view of the growing shortage of wood for laminated wood products and elements, presses of this type are also used to an increasing extent for construction, particularly for windows.

The number of pressing surfaces may be up to 12 and the dimensions of the basic surface ranges from 700 x 2,500 mm to 1,300 x 3,800 mm. The glues used are of varying types, initially, however, the animal glue type of adhesive was used. The pump's overall pressure is up to 40 bars.

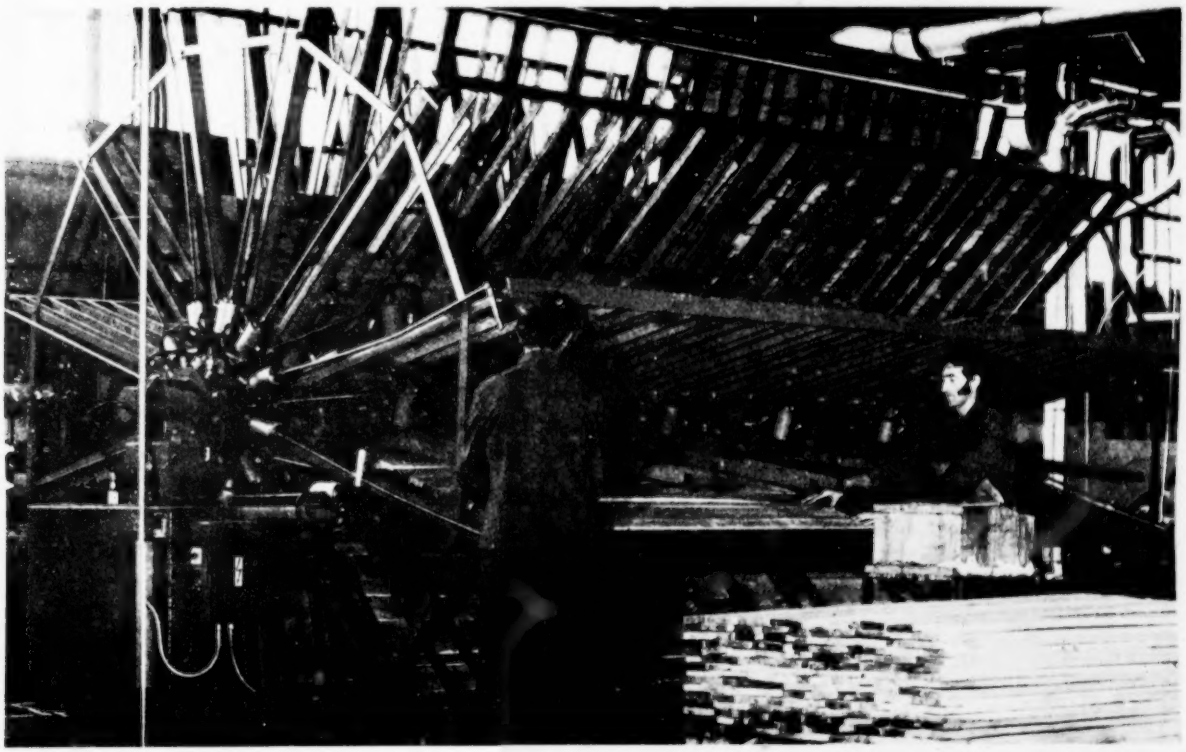


Figure 20.

(d) A casegoods press

This press is a continuous line press: the elements to be pressed enter the machine along a conveyor. An electronic device, located in the middle of the switchboard, allows one to position the casegoods automatically into the very middle of the press. Maximum dimensions of pieces are as follows: 2,200 x 600 x 1,200 mm.

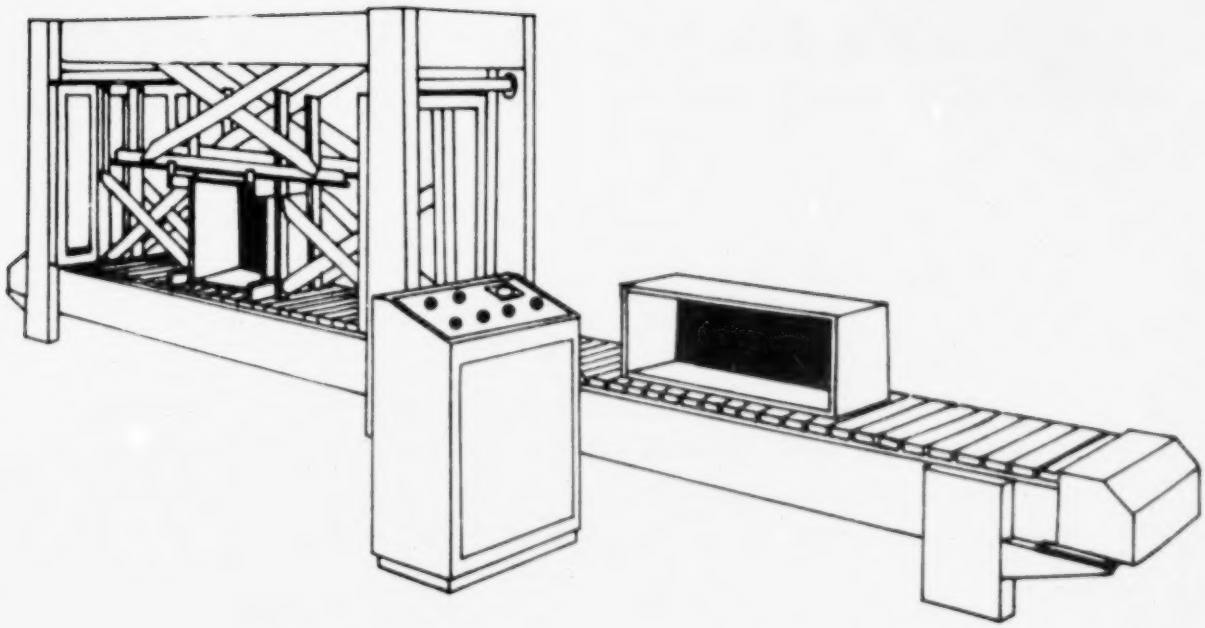


Figure 21.

(e) Air-cushion press

This press is mostly used to glue a foil to a board, whereby basic cushion dimensions are 1,000 x 650 mm. Any number of cushions may be available with this press. The cushion may move 50 mm from one side to the other, and the pressing force of a 1,000 x 650 mm air cushion is 13 tons.

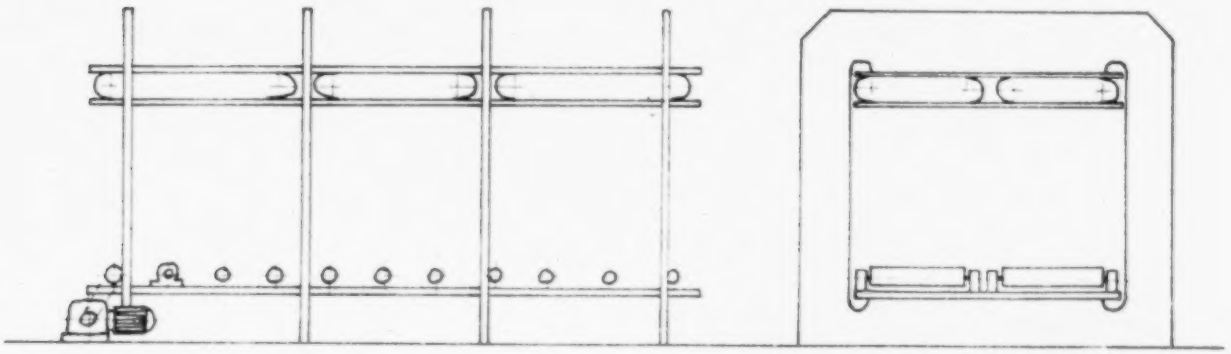


Figure 22.

9. OTHER MACHINES

(a) Brush sanding machine

This machine is used for the sanding of profiled and other small elements of hardwood. Sanding quality may vary, depending on the grain size of the sanding paper, on the one hand, and the brush type, on the other. Sanding width is 200 mm and the cylinder diameter is 350 mm.

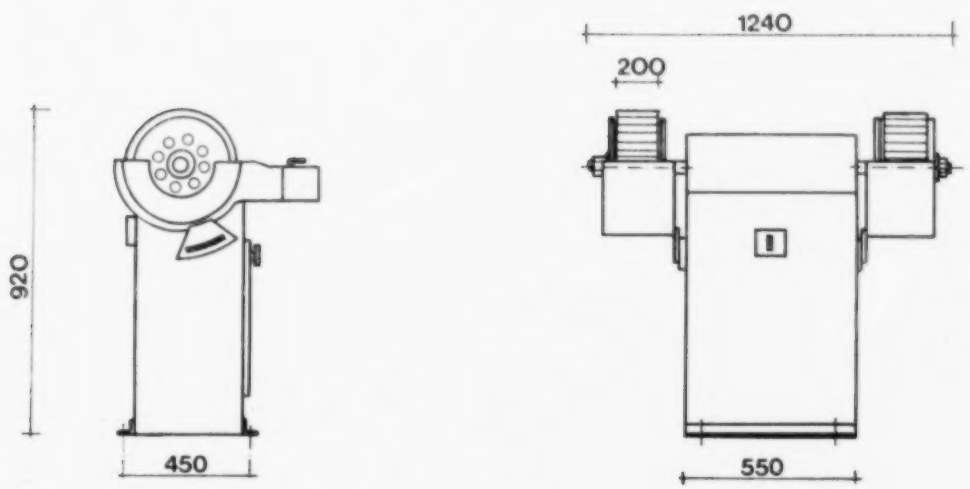


Figure 23.

(b) Hydraulic guillotines for veneer packs

The guillotines manufactured in Yugoslavia are 3,200 mm long and are furnished with a built-in device used to provide an additional cut for fragile veneer. Maximum height of a packet may be 100 mm and its maximum width 800 mm. A double safety device is built in this machine and it prevents accidents (the engine must be switched on by both hands and a photo-cell provides for additional protection).

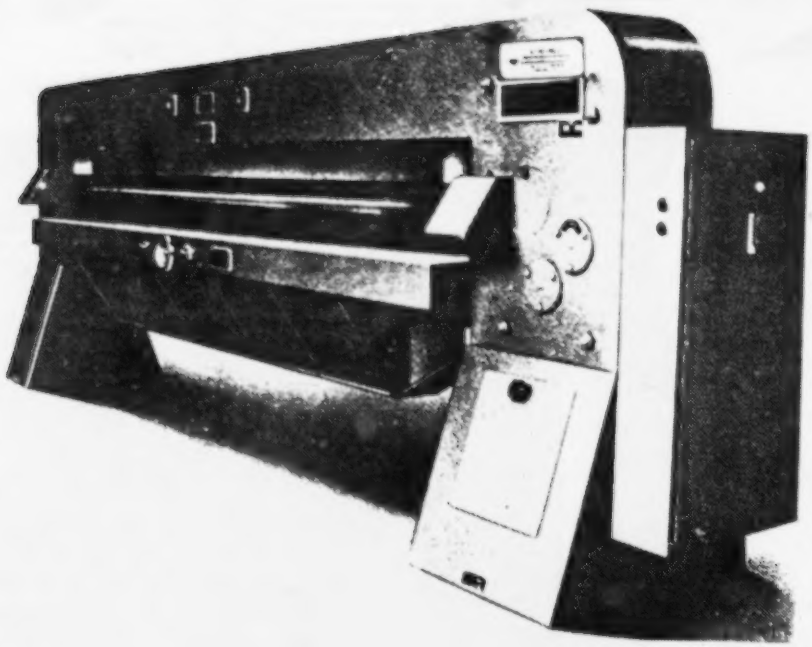


Figure 24.

(c) Veneer splicing machine

With this machine only splicing tape can be used. A new machine, however, that operates with a splicing thread is being developed. Splicing tapes are available in 2 widths: 12 mm and 15 mm. The thickness of veneer ranges from 0.3 to 2.5 mm.

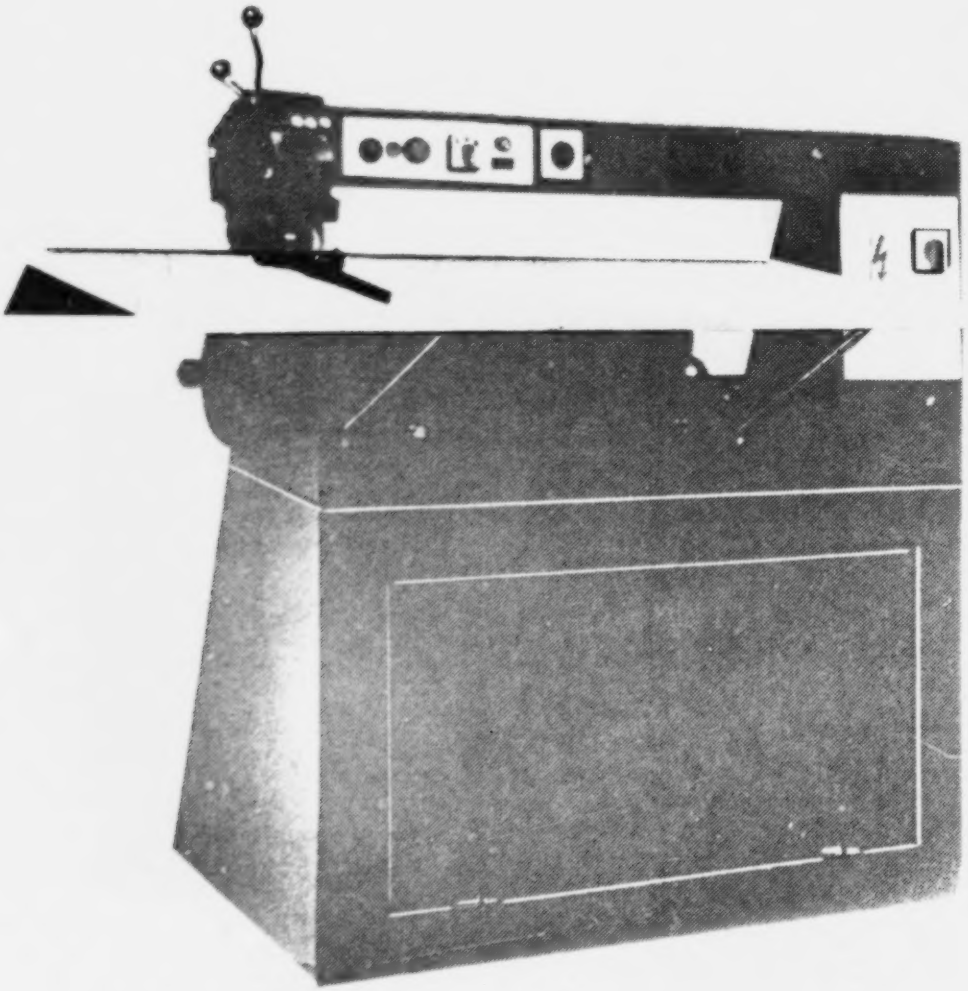


Figure 25.

(d) Feeding device

The device can be coupled to any machine (spindle moulders, table circular saws, etc.) which require automatic feeding of the elements. The feed speed may be regulated in the range of 2 to 25 m/minute, and its engine power is 0.5 kw.

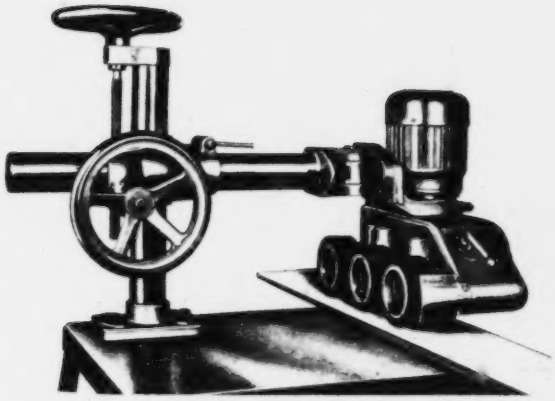


Figure 26.

10. MANUFACTURE OF BAND-SAWS AND MACHINES FOR SAWMILLS

At present Yugoslav manufacturers can supply and produce an entire sawmill with an output capacity of 5,000 to 10,000 m^3 of logs per year. The logs can be up to 8 m long and their diameter may range from 20 to 180 cm.

Within the framework of this programme the following machines are produced: log band-saws whose diameters are 1,100, 1,400, 1,600 and 1,800 mm; band saws with diameters of 900, 1,100, 1,500 and 1,600 mm, as well as hydraulically activated cross-cut saws, and single-blade automatic circular saws for longitudinal sawing.

Blade sharpening machines for the above saws and cutters are also manufactured in Yugoslavia. The wheel diameter for these log band-saws is 1,100 mm, maximum diameter of logs entering the saw is 500 mm, the engine power is 30 kw, and conveyor speed ranges between 0 and 60 m/min.

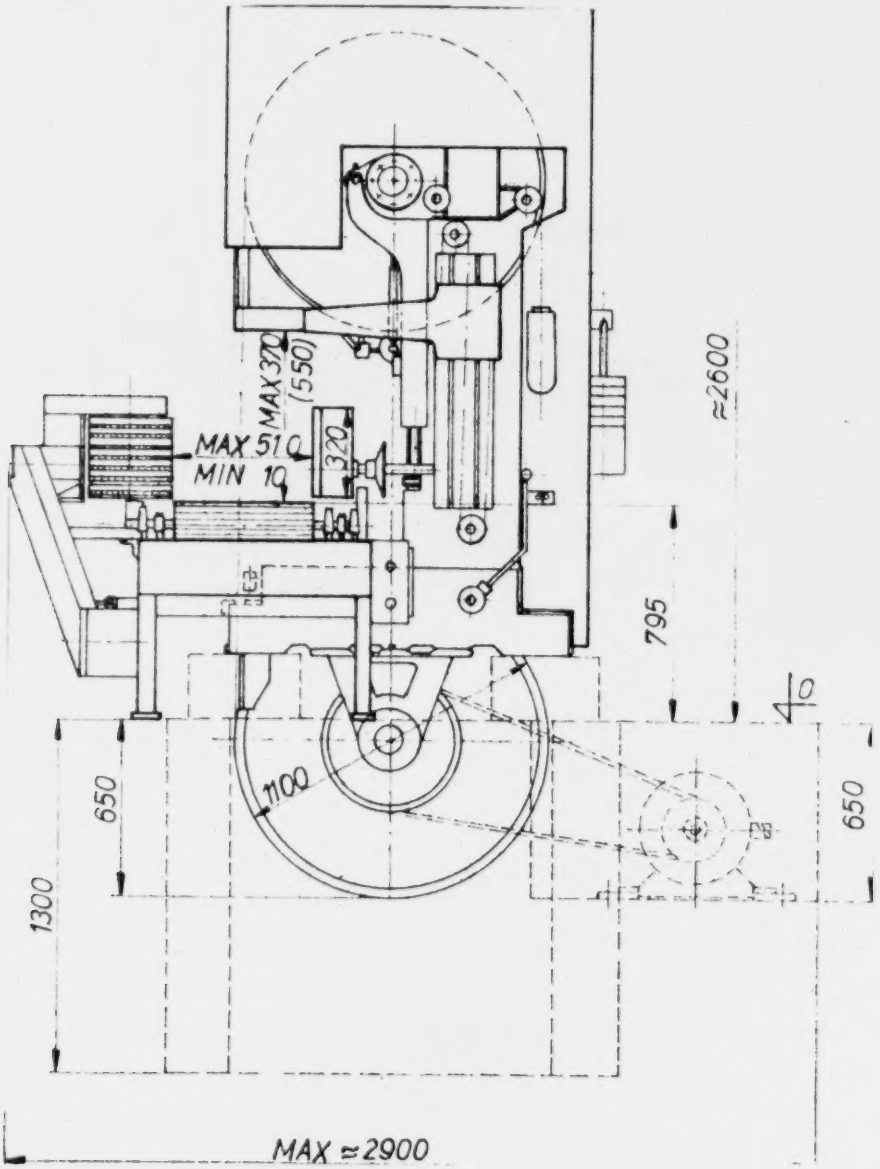


Figure 27.

11. WOOD DRYING KILNS

(a) Softwood drying kilns

Portable drying chambers of simple design and lateral axial fans are at present manufactured in Yugoslavia. The usual speed of the circulating air is 3 to 4 m/sec. Either steam or hot water are used to heat the drying chambers. Capacity of one chamber may go up to 25 m^3. The chambers may be furnished with a manual, semi-automatic or automatic control of the drying process.

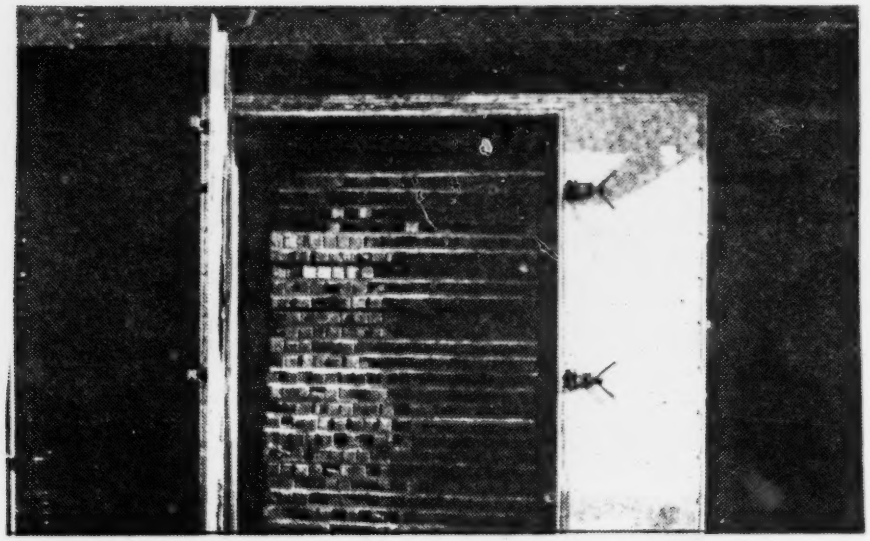


Figure 28.

(b) Hardwood drying kilns

These machines are available with one or 2 rails and/or one or 2 chambers with a volume of up to 48 m^3, as well as 4 chambers with capacity as high as 100 m^3. Axial reversible fans provide for adequate air circulation, and heaters located above the pallet on the opposide side of the fans provide for heat. The chambers may be furnished with a manual, semi-automatic or automatic control of the drying process.

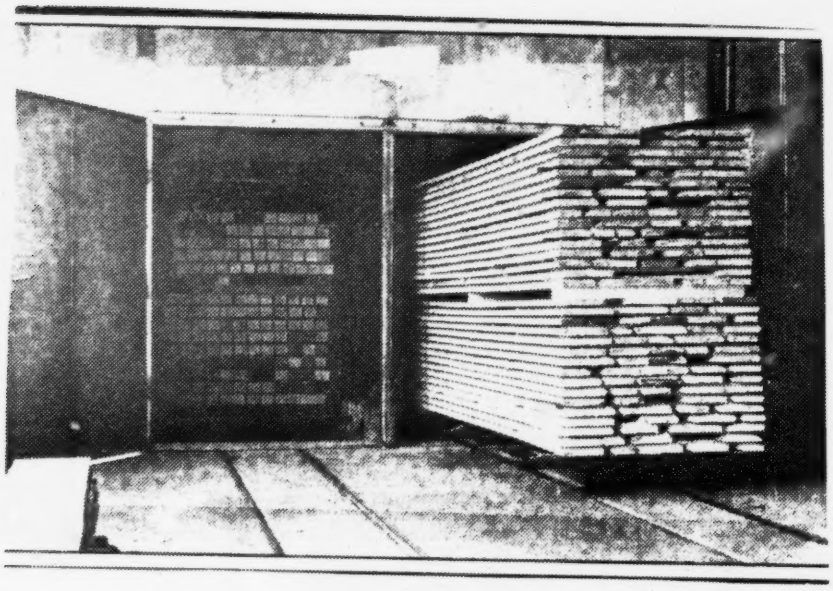


Figure 29.

(c) Pre-drying installations

These are utilized with the purpose of reducing natural drying time by up to 10 times. Velocities of air flow are small and do not surpass 2 m/sec, and the temperature is rather low, i.e., 40° to 50° C. Exposing wood to a pre-drying process may also improve the actual quality obtained in the drying process, which particularly applies to the drying of exotic and very hard wood species. The capacity of the machine may go up to 500 m^3. The control and monitoring of the drying process may be either automatic or manual. Machine feeding and materials transport are performed either by side loaders or forklifts.

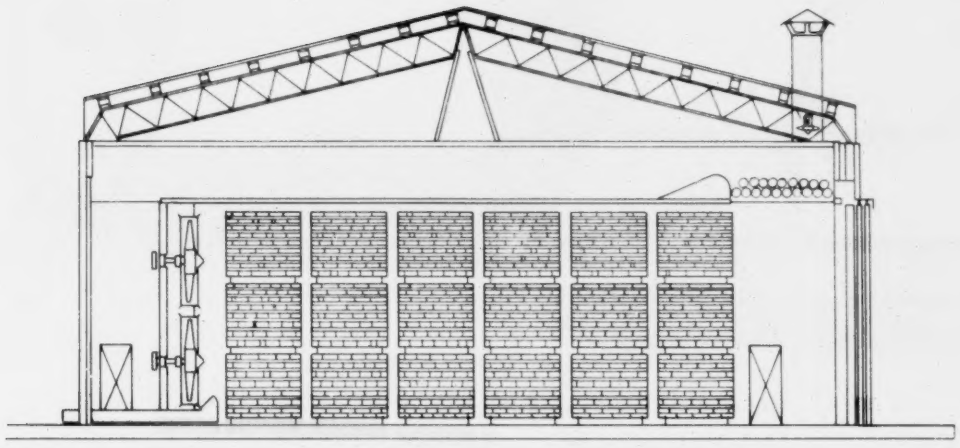


Figure 30.

(d) Wood moisture measuring device

The measuring range of this device is 4 - 60 per cent; maximum thickness of a wood element to be measured in 200 mm. Temperature compensation from - 10° C to + 80° C has been built into this device, which allows one to measure prior to, during and after the processing of the wood.

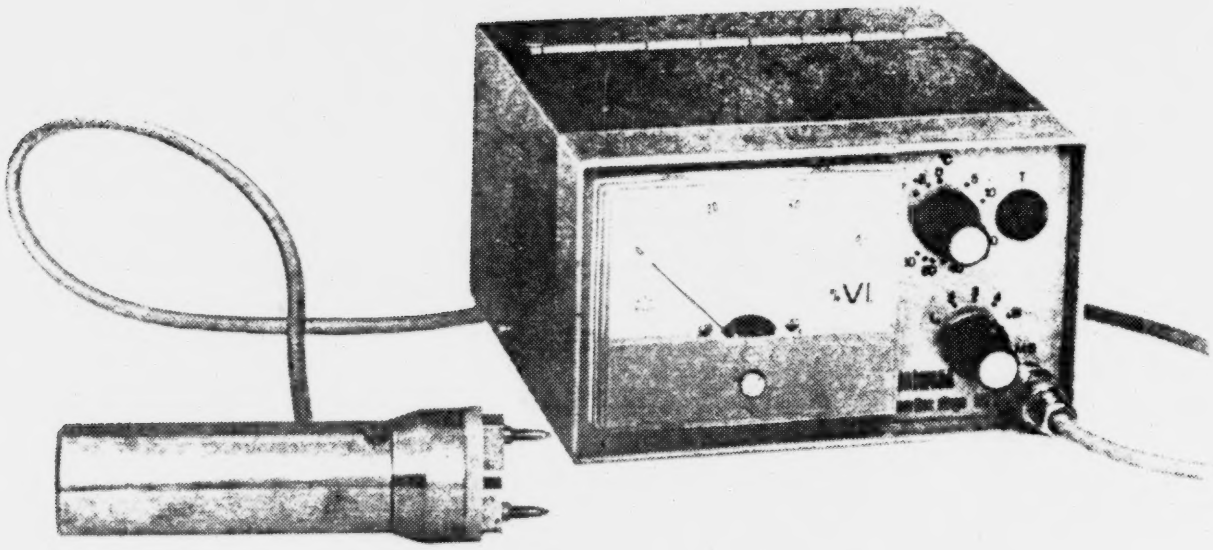


Figure 31.

12. MANUFACTURE OF TRANSPORTATION AND CONVEYING MACHINES

A number of Yugoslav companies produce conveying equipment which may be classified as follows:

(a) Heavy-duty conveyors (roller conveyors, belt conveyors, hand conveyors, etc.) used for the transport of materials in sawmills (Figure 32).

(b) Light conveyors of different design that are used in furniture plants (Figure 33).

(c) Lifting and elevating tables of varying bearing capacities and dimensions (Figure 34).

(d) Fork lifts.

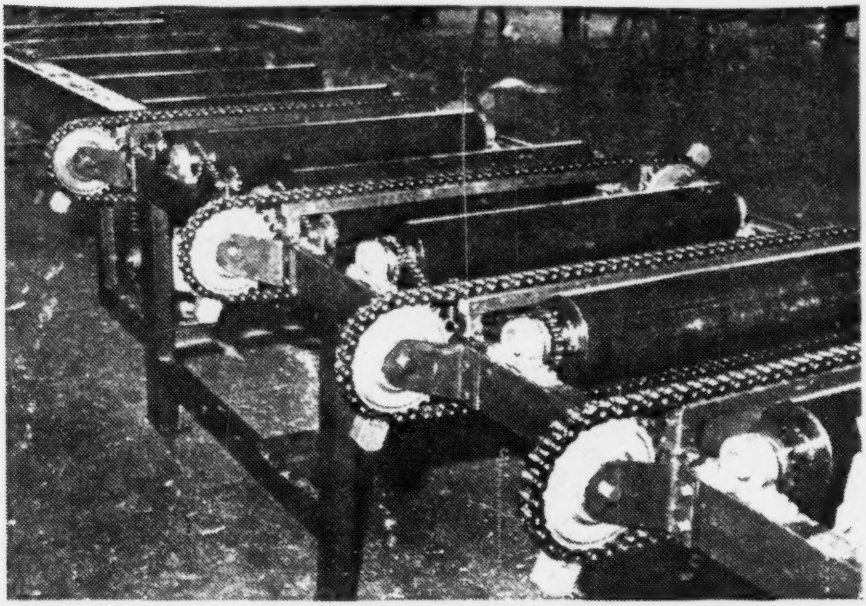


Figure 32. A heavy-duty longitudinal and transverse conveyor.

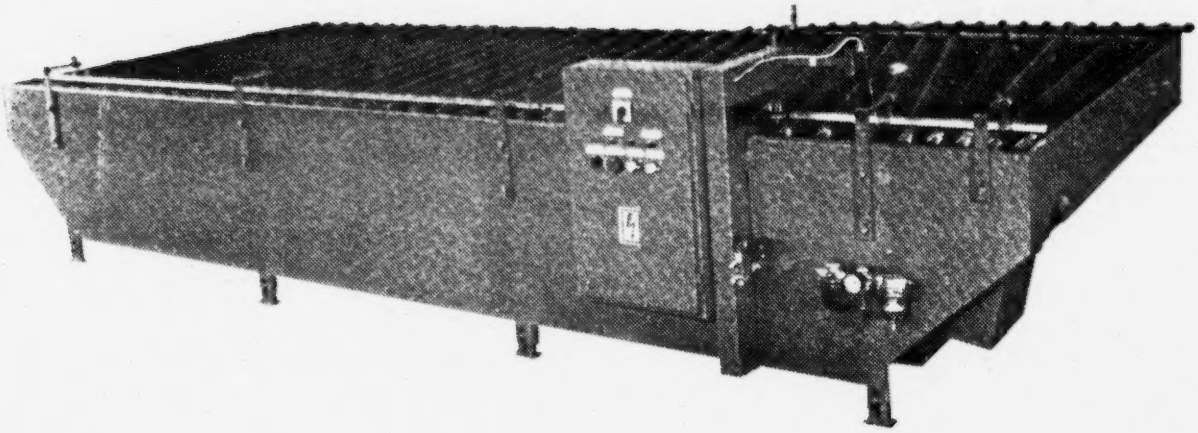


Figure 33. A board-turning device: turning angle is 90°. Lateral turning is also possible. Maximum allowable dimension of the boards is 2,500 x 1,000 mm.

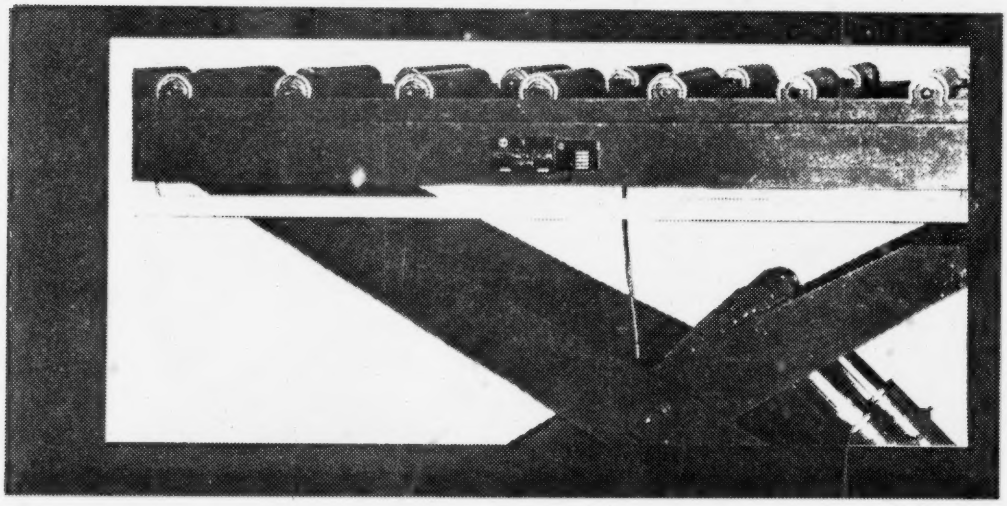


Figure 34. A lifting table, bearing capacity up to 5 tons; dimensions 3,700 x 1,500 mm.

13. MANUFACTURE OF VARNISH DRYING MACHINES

Highly specialized drying machines and/or drying lines required in surface treatment of wood are manufactured in Yugoslavia. Our enterprises produce the following drying lines:

(a) For the surface treatment of small profiled elements (e.g. elements used for wall panels, floors, etc.).

(b) Surface treatment of casegoods and/or assembled chairs.

(c) Surface treatment of boards for doors and elements for casegoods.

(d) Surface treatment of elements for colonial style chairs.

(e) Surface treatment of elements for the construction industry.

(f) Surface treatment of elements (for the construction industry) covered by glazed coatings.

(g) Tailor-made lines.

14. PROCESSING LINE FOR ELEMENTS USED IN THE MANUFACTURING OF COLONIAL CHAIRS

The line is made up of 2 parts:

(a) A line for the varnishing of wood curtain rails and planed elements with a single immersion.

(b) A line for seats and backs with a triple-immersion. The capacity of the line is about 150 pieces/h, the heating medium used is steam, hot water or oil. Twelve to 16 persons are employed in this line.

A processing line for surface treatment of elements for colonial chairs (output capacity: 150 chairs/hour) is given in Figure 35. The key to the numbers in Figure 35 is given hereunder:

1. Suspended chain transporter
2. Suspended carts with supports for elements
3. Drying chamber
4. Chamber with tub and immersing device
5, 6, 7. Drying chambers
8. Device for fixation of elements
9. Device for removal of elements from supports

10.	Leaching chamber
11.	Tub with an operation grid and exhausting wall
12.	Varnishing chambers
13.	Traction chain transporter
14.	Carts used in different levels
15, 16, 17, 18, 19, 20	Exhausting walls
21	Drying chambers
22.	Cooling device
23.	Sanding tables
24.	Fresh air intake
25.	Electrical switching box.

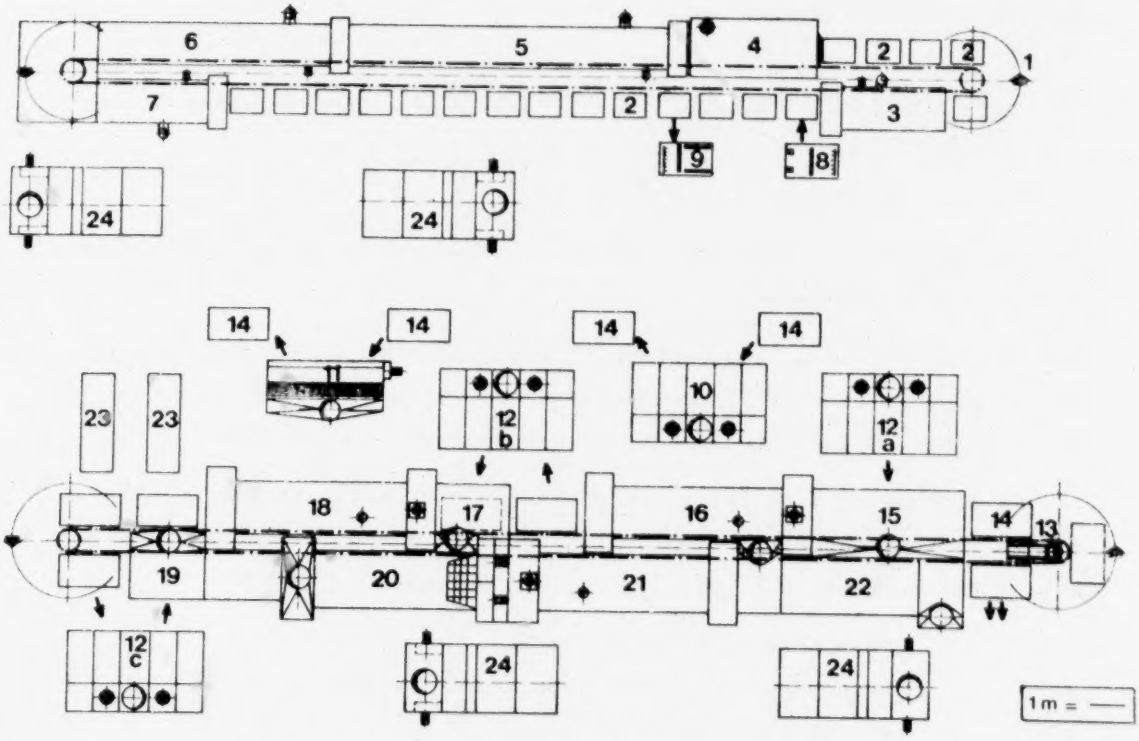


Figure 35.

15. MANUFACTURE OF PACKAGING MACHINES

Automatic machines for packaging in plastic foil are used by woodworking plants primarily when using carton boxes for furniture (made of solid wood or elements of casegoods), windows, doors, flooring, sawnwood, etc. A major advantage of an automatic machine lies in its large output capacity, bearing in mind that up to 5,000 packages can be prepared in 8 hours. Splicing tape is also the least expensive packaging material used for the above purpose. Fully automated packaging is, furthermore, possible.

Machines used for automatic packaging with a splicing tape

Conveyor belts may be attached to this type of machine, which results in improved and less complex handling, and increased output capacity. Maximem frame dimensions are as follows: 2,000 x 2,000 mm. Splicing tape widths available are 12 and 16 mm, and its thickness is 0.8 mm. Tape welding temperature is 190° C to 230° C and the machine's output capacity is up to 500 packages per hour.

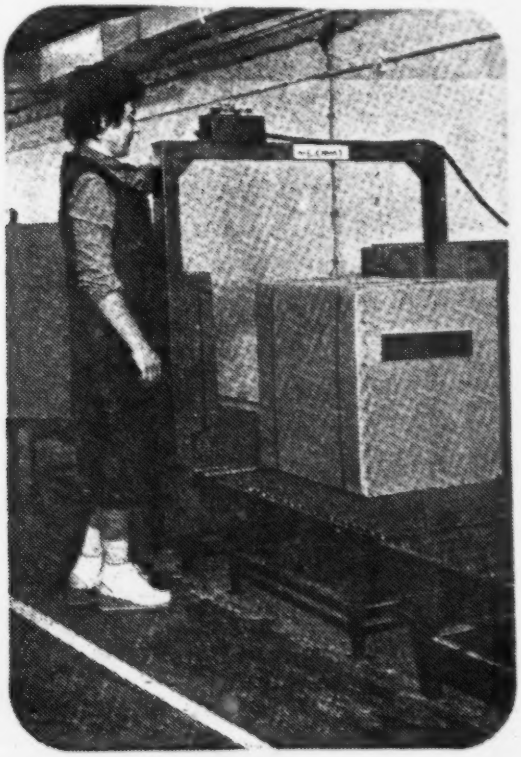


Figure 36.

16. PRODUCTION OF DUST AND CHIP EXHAUSTING DEVICES

Filtering systems based on regeneration of exhausted air are manufactured in Yugoslavia. An advantage of the system lies in the fact that it provides for maximum fire safety; fire risk is thus limited to only a small area (1 or 2 filtering cells). In a classical system of exhausting, however, an entire exhausting system is usually affected by a fire. Other benefits of this system are as follows: a very high level of filtering, maximum safety of operation, and energy saving. The system is, furthermore, very flexible in terms of output capacity adjustments, and its operational costs are rather low.

The cells of the system with in-built filters have a capacity of 3,000 to 230,000 m^3 of filtered air per hour; in addition, 3 to 200 m^3 of solid material is eliminated per hour. A chain-conveyor system takes care of transport of wastes into a silo. When required, automatic fire extinguishing devices may also be built into the system. Filtered air is recycled from the cells into operational areas, resulting in considerable heat savings.

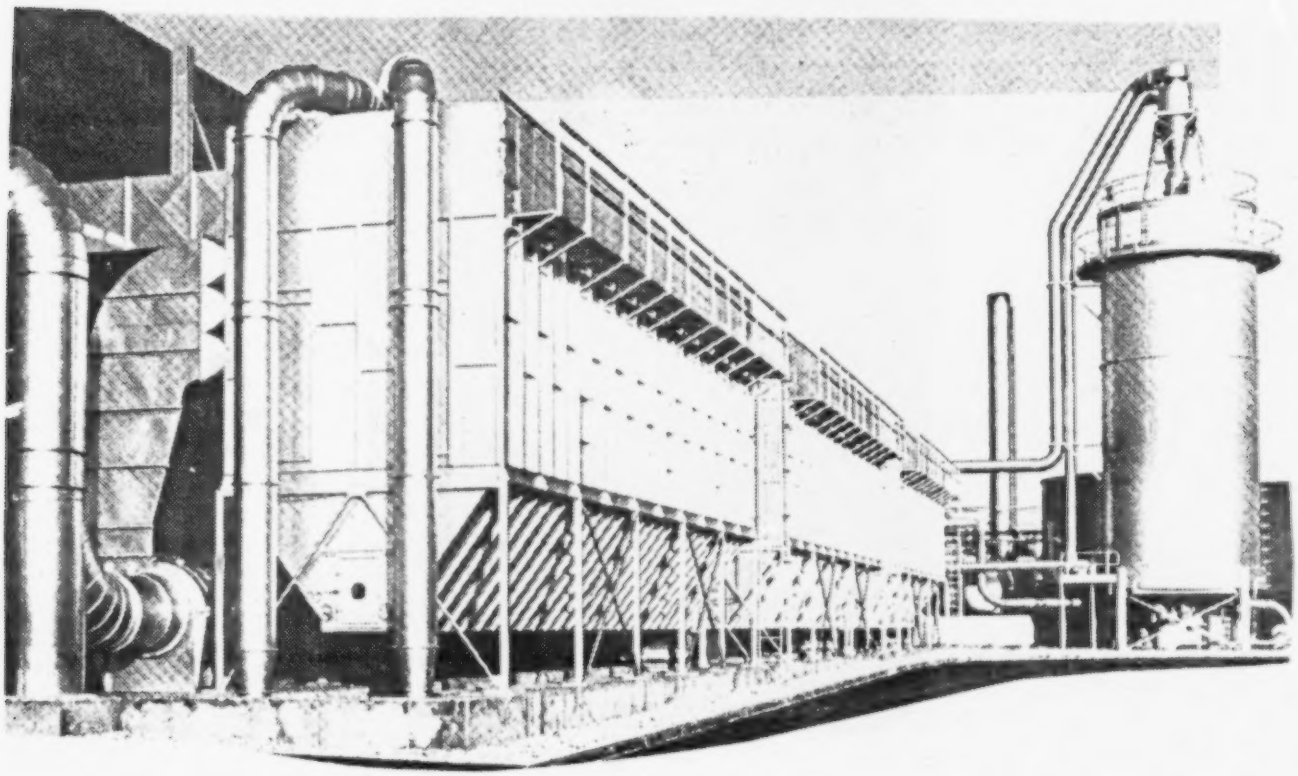


Figure 37.

17. MANUFACTURE OF POWER STATIONS FIRED ON SOLID FUEL AND/OR WOOD PROCESSING WASTES

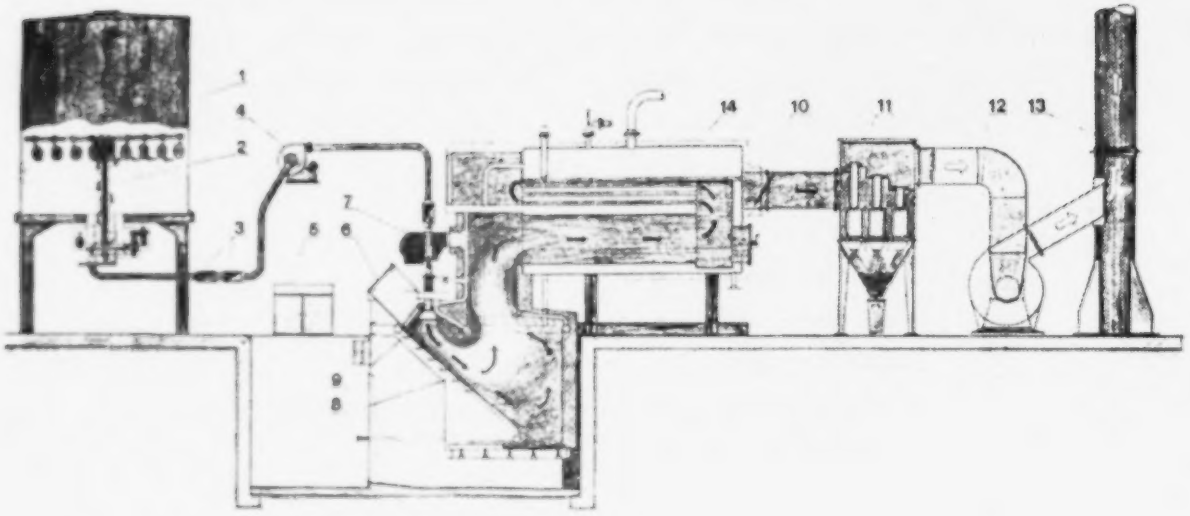
All sorts of wastes are obtained in the woodworking industry, such as: sawdust, wood powder, off-cuts, bark, etc. When fully automated incineration of wastes is aimed at, fuel storage (dozing, exhausting and ash removal procedures) has to be provided as well as an adequate boiler.

Fundamental parts of a simple waste incinerating device are as follows:

- A waste storage silo
- An unloading device
- A conveyor fan
- A boiler (that can be controlled and regulated)
- An exhausting device
- An exhausting fan
- A smoke stack

A number of other elements may also be used to safeguard viable and profitable operation of the system as a whole.

A layout plan of a power station fired on wood processing wastes is given in Figure 38 on the following page.



1. Silo
2. Cutter
3. Safety flap
4. Conveying fan
5. Switchboard
6. Door for pieces of woodprocessing waste
7. Burner
8. Transverse grid
9. Dozing nozzle
10. Smoke flap
11. Smoke filter
12. Exhaust gas fan
13. Smoke stack
14. Boiler

Figure 38. Layout of power station fired on wood processing wastes.

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TOOL AND MACHINE MAINTENANCE*

Prepared by

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1. MAINTENANCE OF BLADES FOR WOODWORKING

Woodworking tools play a very significant part in mechanical processing of wood; the profitability of a number of woodworking plants will depend upon them. Tools are considered well prepared and suitable when their life is long enough and their durability adequate. Proper sharpening procedures and use will certainly have decisive influence upon the tools' life; the quality of steel they are made of will, on the other hand, play a part in blades' durability, and optimum performance is only attained with adequately sharpened and properly used tools.

The technology used for sharpening saw blades and knives has made a big step forward in the last ten years; electronics has come to play a significant role in this field. The use of computer-supported machines provides an enormous advantage when compared with those used a few decades ago, and this implies both manufacturing accuracy and quality of sharpening and grinding.

2. MATERIALS USED IN THE MANUFACTURING OF BLADES

Saw blades are made from chrome-vanadium steel with a limited (0.6%) carbon content, with addition of other elements, such as silicon, nickel. manganese, and some alloys. High-alloy steel of varying quality grades is used for veneer knives, planer knives, surface scrapers, borers, and other sophisticated cutters. Blades and knives for laminates and other hard materials are plated with "Widia" (an alloy of great hardness, equal to that of carbide). The maintenance of blades made from carbide-alloys is extremely demanding and costly, which is one of the reasons for their substitution by synthetic diamond. The sharpening and other maintenance procedures are adjusted to suit the specific materials from which blades or knives are made.

3. SHARPENING MACHINES AND EQUIPMENT

Sharpening devices of varying forms and commodities are used for blades and knives. The composition of sharpening devices or grinding wheels may differ to a large extent. Ceramic grinding wheels or those

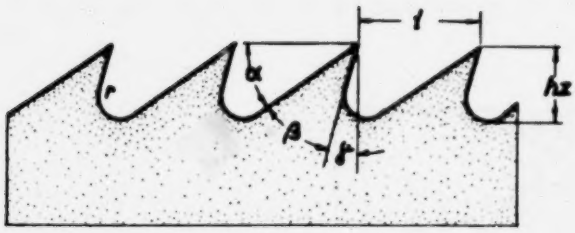
made of corundum and silicon grains are used for the sharpening of medium- and high-alloy steels; the size of grains depends on desired sharpening procedures. Usually wheels are used with grain of mesh size ranging from 40 to 120. The hardness of the grinding wheels is of paramount importance in the sharpening of tools. The following rule of thumb is applied: the harder the steel to be sharpened, the softer is the grinding wheel used. The hardness of grinding and sharpening wheels is designated with letters: I, J, K. H are used for low-toughness, L and M for medium-toughness and P, R and subsequent letters for high-toughness grinding and sharpening wheels. The porosity of grinding wheels also plays its part in the sharpening of tools: the larger the surface to sharpen the more porous is the sharpening device used.

Pre-grinding is recommended for blades plated with "Widia" for this purpose a coarse-grain (e.g. D 150) grinding wheel is first used, followed by a D 30 grinding wheel. Generally speaking, diamond sharpening and/or grinding devices are used for the hardness similar to that of carbide; exceptionally, grinding wheels with silicon grains or borazon plates may be used for very rough grinding.

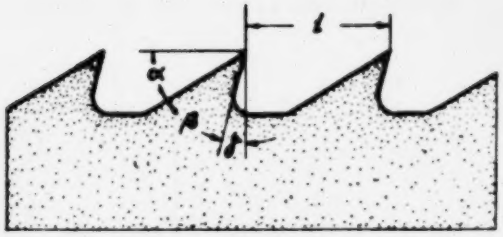
During sharpening the tip of the blade will become hot, thus less tough, and the result may be a very serious defect. It is possible to avoid this risk by using a coolant in the course of sharpening. At the same time the sharpening device must be kept clean and chip removal provided. As the abrasive wheel becomes clogged up, the surface is trued using a diamond-ended "pencil" that is traversed horizontally across it. (This way contours can also be developed on abrasive wheels.)

4. BAND-SAW BLADES

The tips of the saw blade's teeth are bent to the left and to the right by 1/3rd of the blade's thickness (spring-set). Compression procedure is also used (swage-set). If blade teeth tips are swaged their surface should be hardened by a high-frequency procedure. In this manner durability of the blades can be increased by about 50 per cent.



The geometry of teeth of band saw blades used for hardwood species with a fast feed.



The geometry of teeth of band saw blades used for softwood species.

The geometry of the tips of teeth of band-saw blades is as follows:

Distance between teeth (t):	22 - 28 mm
Height of teeth (hz):	1 t
Radius of the gullet between teeth (r):	6 - 8 mm
Rake angle (α):	20 - 31°
Bevel angle (γ):	14 - 18°
Cutting angle (β):	45 - 52°

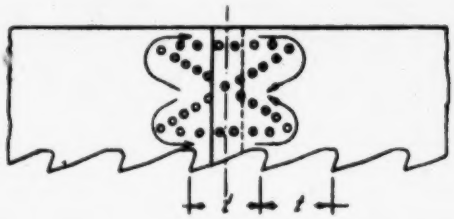
The geometry depends upon the wood species, condition of wood (fresh or dried), rate of feed, etc.

5. SHARPENING OF WIDE BAND-SAW BLADES

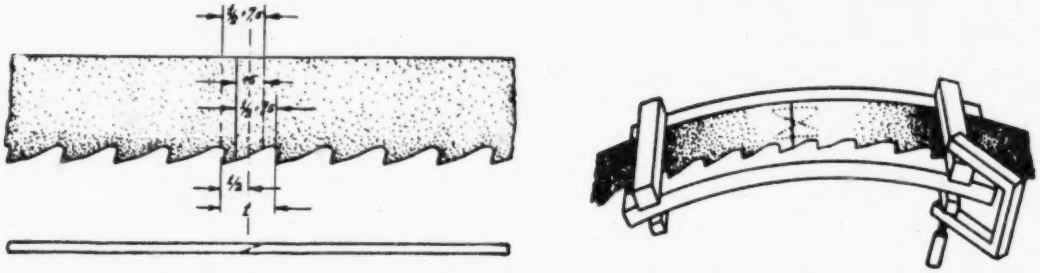
The width of the blade depends on band wheel design. At any time of operation the tips of the teeth must protrude over the rim of the wheels by 10 to 15 mm. Band-saw wheels must be convex if we want the blade to fit perfectly. Blade thickness will depend on its width, and is usually 1/1,000th of the wheel's diameter; if the wheel diameter is large, e.g. 1,800 mm, the blade thickness is usually reduced by 0.1 mm.

A stage in the band-saw blade preparation is the brazing of the blade. The blades are supplied in coils of 50 m; different brazing or welding procedures are used, from scarf jointing and butt joint welding to spot welding.

In certain countries steel is bought in rolls and then the teeth are punched out after the desired length of blade has been cut from the foil.

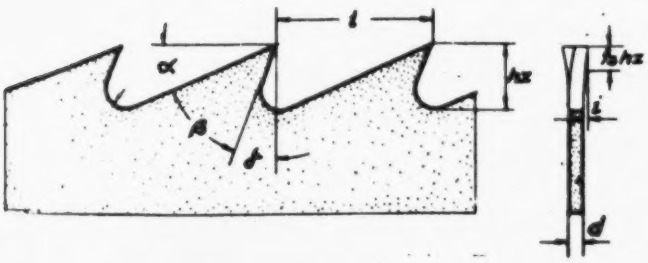


The weld is hammered with a cross-headed or a point-headed hammer to relieve stresses in welding.

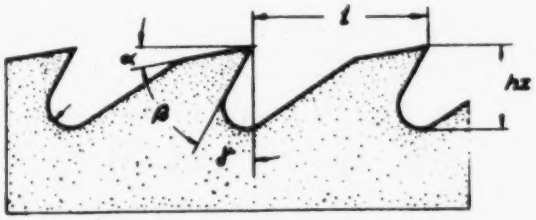


Blade welding and smoothening

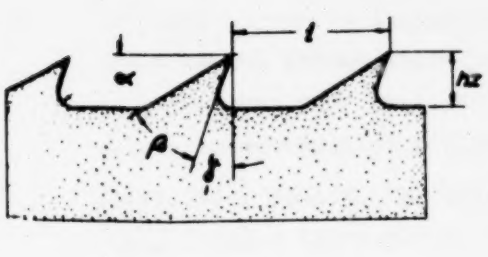
Each of the above welding procedures can only be performed with adequate equipment.



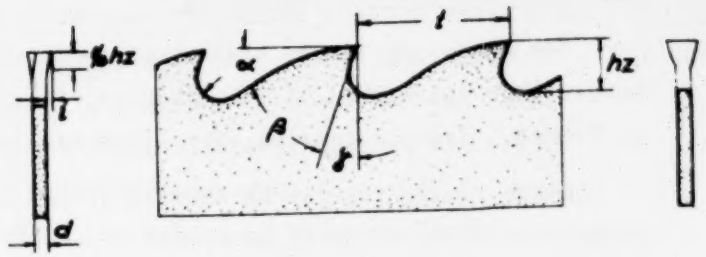
Close-pitch saw blade for softwood species.



Close-pitch front-bevel saw blade for softwood species.

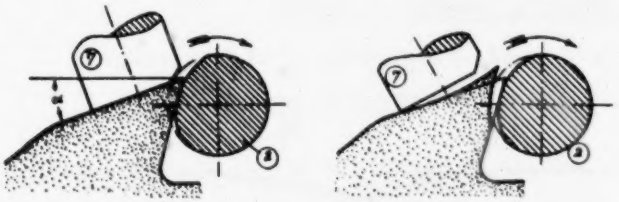


Wide-pitch saw blade for very soft and freshly felled logs.



"American" pitch for hardwood species; teeth tips are compressed, and, if necessary, tipped with stellite.

The geometry, i.e. shape and size, of the tips of teeth will depend on species of wood, its condition, thickness of the blade, etc. The distance between teeth points (pitch) (t) ranges between 30 and 60 mm, and the height of teeth (hz) is 1/3rd of pitch. The angle (γ) of the teeth is very significant (γ = 18 to 25°), particularly when tips of the teeth are swaged. The cutting angle (β) depends on the wood's hardness (β = 45 to 55). The rake angle (α) and the bevel are also determined by blade manufacturers, taking into account wood species and other parameters.



CORRECT WRONG

Swaging (compression) of the tips of teeth

The finish of a sawn surface will be smooth when blade teeth are swaged; tips of teeth may also be improved with stellite, which will result in far longer durability of band-saw blades when tropical species are sawn, and the blade will thus wander much less than without this additional treatment.

(a) Band-saw blades' tensioning

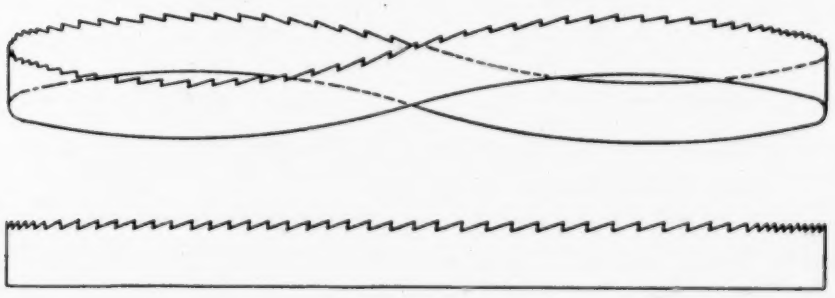
The wandering of the blade back and forth during sawing can be prevented when the middle of the blade is elongated, i.e. when tensioning is performed. Special tensioning rollers are used for this purpose.

Blade tensioning can be checked if the blade is put onto a levelling table, the blade slightly bent, and a ruler is put onto the blade's back side at an angle of 90°. A bulge will then be noticeable under the ruler. The same is done when the blade is bent in the opposite direction. The gap must be as wide as the convexity of the band wheel.

Some elongation is present along the entire length of the blade, as well as its width, except at its back side; it is therefore recommended for wide band-saw blades to be rolled in such a way that there is a slight bulge or curve on its back side. The curve should be 0.5 to 1.0 mm for every 1.5 m length. For narrow and thinner blades the back side of the blade should be completely flat. These should have no curve or bulge whatsoever.

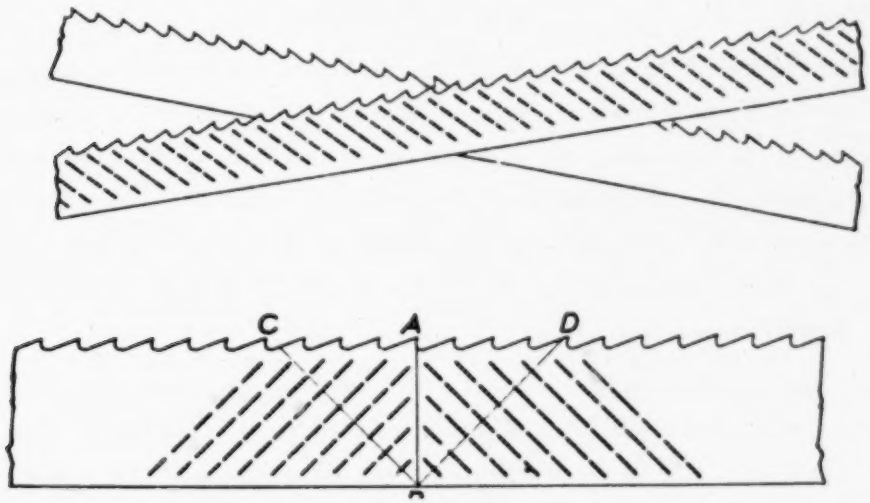
The importance of the tensioning of band-saw blades is quite obvious if they are to oeprate properly. When the tension is inadequate the blade will wander back and forth, develop cracks, vibrate or even break.

(b) Band-saw blade bending (Number 8 form)



Band-saw blade bending in the form of number 8.

The bending of a band-saw blade is a grave fault caused by its improper use or by inadequate welding. The bending in the form of a number 8 may be observed when the blade is put onto a flat surface (e.g. ground) and it will bend in a number 8 form on its own. This defect may develop in a new blade due to its overloading, i.e. when blows occur during the sawing. The defect may be corrected by hammering it with a cross-shaped hammer the weight of which is 1 kilo. Both sides of the blade must be hammered under an angle of 45°.



Repairing blade bending by hammering
(with a cross-shaped hammer).

(c) Cracks and other defects of saw blades

Saw blade cracking is not a rate defect in band-saws; the causes are manifold:

(i) Overtensioned blade in the machine: In this case cracks develop on the front or the back side of the blade, i.e. between teeth. Average value of tension (tensile stress) is usually 5 to 7 tons for a 140 to 200 mm wide and 1.2 to 1.45 mm thick blade.

(ii) When the gullet between 2 teeth is very sharp, and burnt due to rough sharpening with a grinding wheel cracks will also develop; great care must be taken therefore to keep sharpened surfaces smooth and not burnt. After rough sharpening, a soft grinding wheel must additionally be used to avoid this defect. The gullet between 2 teeth must also have a radius of at least 4 mm, which can be obtained and maintained by forming the profile of the grinding wheel.

(iii) Excessive, insufficient, as well as unbalanced or non-proportionate internal stress, may also result in cracks.

(iv) Excessive pitch in such saw blades that are used for the sawing of hardwood, particularly in the winter time. Before a winter begins it is necessary to procure blades with a small pitch, which is suitable for the sawing of frozen wood, when a balanced rate of sawing and rate of feed must be supported by a small-pitch blade. This problem often causes enormous material and capacity losses in our sawmills.

(v) Inadequate teeth angles: The tooth bevel plays a very significant role. When the angle of the tooth proves to be too small the risk develops that the blade will break due to overload; if the angle is too large, however, cracks will develop in the surface between the teeth. This defect becomes a problem when individual work pieces to be sawn are very different from each other, and when a number of blades of differing shapes are sharpened with one sharpening machine only.

(vi) Cleanliness of the blade and band wheel: Prior to all sharpening procedures the blade must be cleaned of all stains; the cleanliness of the woodworking machine, i.e. the band-saw itself, should also be paid atention to. All sawdust must be collected by exhausting devices; when sawdust is left on the band wheel surfaces, cracking of the saw blade will result.

(vii) The positioning of band wheels on the sawing machine is also very important: The wheels must be assembled in a strict vertical position one above the other, which is significant at the time when the bearings are changed and when other major maintenance procedures are carried out. The fixing and ability of the guides is also to be emphasized in this connexion. The weight of the log feed carriage, and the precision when fixing the carriage rails, also have an impact upon the new blade; the angle between the rails and the face of the band wheels must always be 90°.

(viii) Incorrect and unequal swaging or spring setting also causes cracks.

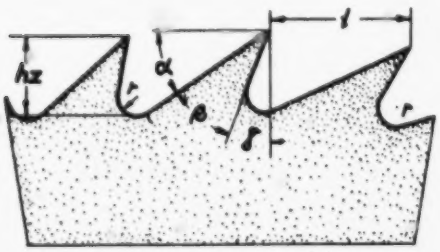
6. CIRCULAR SAWS FOR EDGING AND TRIMMING

Circular saws for edging and trimming are used in a sawmill in which sawn wood is partially processed into elements of specific dimensions (broadleaved species) or into boards (coniferous species) that must be trimmed.

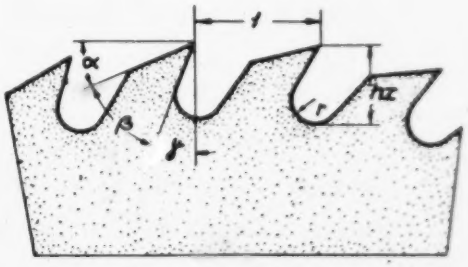
(a) Thickness of blades

In new sawmills usually usually only circular saws are used for coarse sawing; hence their larger thickness than that of other circular saws. The thickness of blades used for coarse sawing ranges from 2.5 to 3.5 mm.

The shape of teeth of a circular saw for longitudinal cutting is shown hereunder:

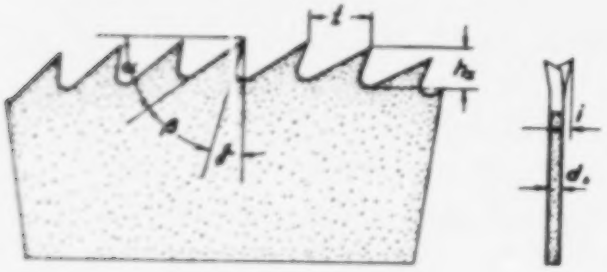


Close-pitch circular saw for longitudinal cutting of softwood species.

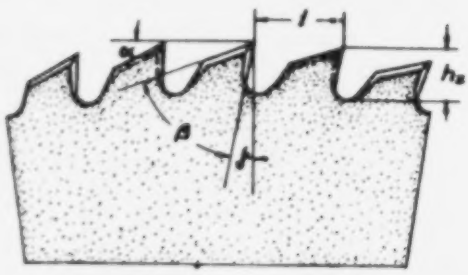


Close-pitch front-bevel circular saw for rough cutting of softwood and hardwood species.

The corresponding shape of teeth of a circular saw for cross-cutting is:



Close-pitch circular saw for cross-cutting.



Close-pitch circular saw for hardwood cross-cutting.

(b) Shape of teeth

For coarse sawing usually saws with sharp teeth-angles are used (particularly for softwood), or those with a very close pitch (particularly for hardwood).

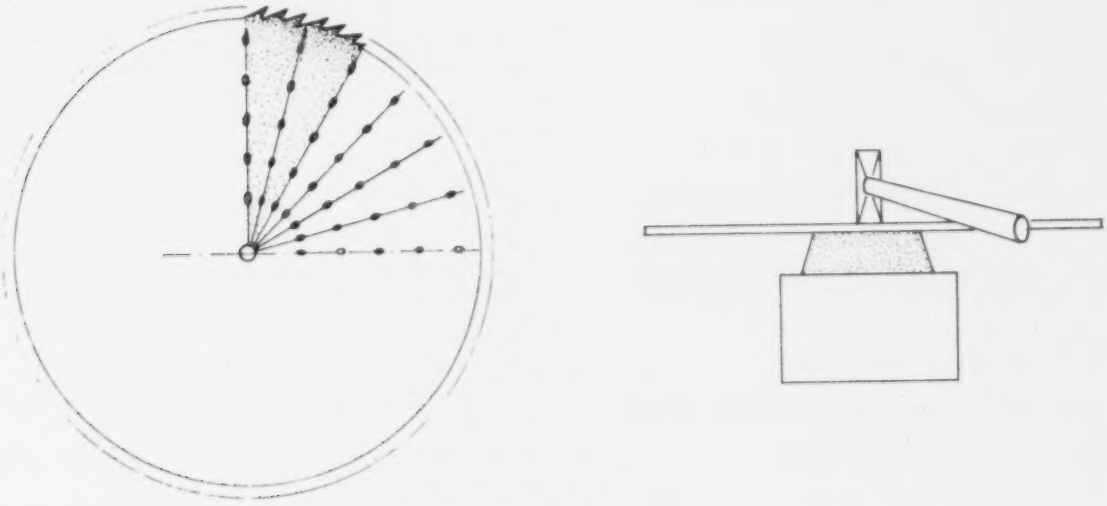
In all cases the tooth cutting angles range from 45 to 55°, the angle being smaller for softwood species, and larger for hardwood. The tooth bevel (δ) varies between 20° and 30° for circular saws used in sawmills. The angle is smaller in circular saws used for facing and larger in those used for longitudinal cutting (ripping). Transverse sharpening of teeth is not used in this type of circular saw since it would reduce the durability of the blades. An exception to the above rule is made cor circular saw blades used for the cutting of boards to dimensions. When transverse teeth sharpening is used, the angle should be 10°.

(c) Pitch and height of teeth

The pitch of circular saws used for coarse cutting is 30 to 45 mm; the pitch is the largest in circular saw blades used for ripping of softwood, and smaller in the blades used for the cross-cutting of hardwood, obviously in relation to the hardness of wood: the harder the wood species and the larger the load to which the blade is exposed, the smaller the pitch.

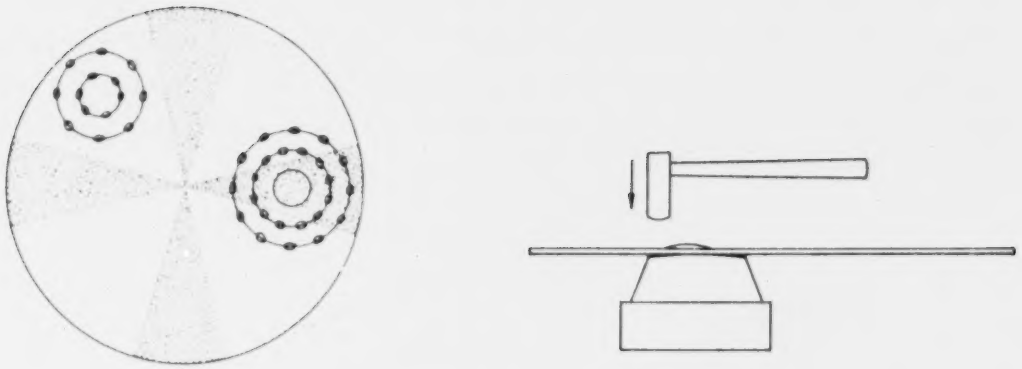
(d) Durability of circular saw blades

Circular saw blades used for ripping are usually changed at intervals of 6 to 8 hours, and the cross-cutting saws every 4 hours. Whenever changing the blade the teeth are swaged and sharpened. The blade is also thoroughly examined to see whether the blade has bent or deviated, and whether a bulge has occurred; such defects must be corrected immediately prior to sharpening.



Tensioning of circular saw blades
with a hammer and an anvil.

The edges of a circular saw blade are often burnt or overheated during operation, which results in bulges that will cause problems when sawing. This defect must be eliminated as soon as possible, by using a single-face hammer and an anvil.



Removal of bulges in a circular saw blade.

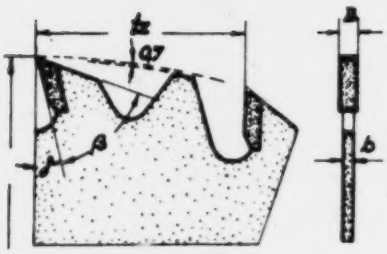
7. MAINTENANCE OF WIDIA (TUNGSTEN CARBIDE) CIRCULAR SAW BLADES

Circular saw blades with Widia (tungsten carbide) inserted tips are used for hardwood and boards in which a phenol-resin glue has been used. The maintenance of these blades is rather demanding due to the design of the tips of their teeth. Mechanical sharpening is the only acceptable procedure with these blades. The sharpening or grinding must be done on a regular basis to avoid damaged tips of the teeth caused by extreme stress during operation. Prior to sharpening the blades must be thoroughly cleaned to remove any resin, cellulose or similar stains. The blades are immersed into a chemical solution that will dissolve all such stains.

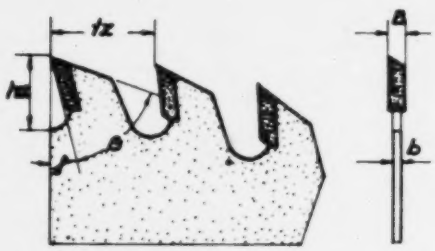
Machines of varying designs are used for sharpening - with diamond-impregnated grinding wheels - and this is entrusted to the most skilled workers. The progress made recently in this field is enormous: double-layer diamond impregnated grinding wheels with a large diameter are used; the grinding wheel oscillates during rotation, electronic probes are applied to examine the dullness of blades and to feed a computer with relevant data that will eventually operate the grinding machine and automatically monitor blade chip and grinding time, set geometrical data for

different blades, etc. Individual parameters, shape and dimensions of the blades must be fed into such a machine, which will all depend on their design, and specific materials they are used for. Such machines are still more the exception than the rule. Tungsten carbide-tipped cutting tools are sharpened using diamond wheels. When these become clogged up they are cleaned by applying cleansing liquids which are supplied by the producers of the wheels.

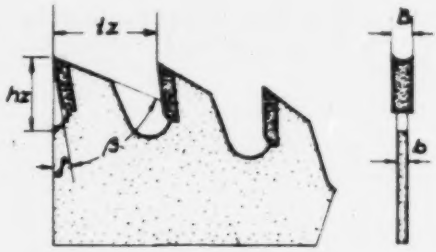
The following illustrates the shape of teeth in widia circular saw blades:



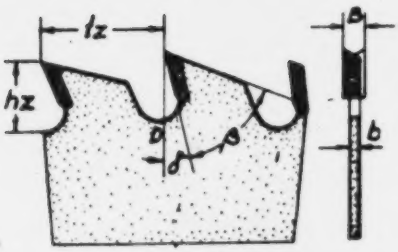
Tungsten carbide-tipped, and a safety device (0.7) that prevents backlash when solid wood is cut.



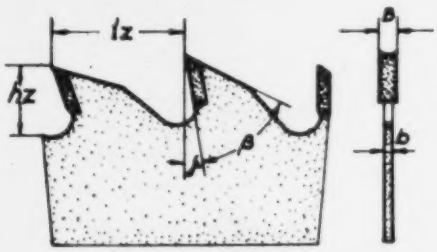
Circular saw teeth for size-cutting of particle and other boards; the right board edge is fine-cut.



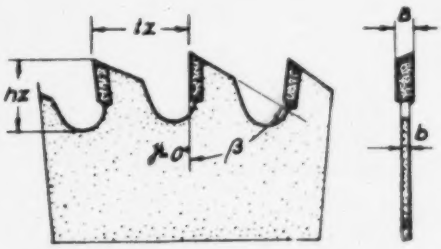
Circular saw teeth for veneered boards and fine cutting. The front end of teeth is sharpened to have a semi-circular shape.



Circular saw teeth geometry for solid-wood and boards; the back end of teeth is sharpened to have an oblique shape.



Circular saw blade for coarse cutting of solidwood and boards, with a very wide-pitch; the back end of teeth is sharpened to have an oblique shape. The blade is suited for manual feed.



Circular saw blade for size-cutting of particle and other boards; the left board edge is fine-cut.

8. BORERS AND MORTISING TOOLS FOR WOOD AND WOOD-BASED MATERIALS

Borers of varying design are used in woodworking. In all designs, however, the cutting edge suits the specific purpose for which the borer or mortising tool is used, e.g. for dowel boring, removal of knots, etc. The geometry, i.e. shape and dimensions, of cutting edges is adapted to the specific purpose, as indicated in the figures below:

For small-depth machine boring

For deep machine boring (e.g. 100 mm)

For manual boring

For deep manual boring

For hardwood machine boring

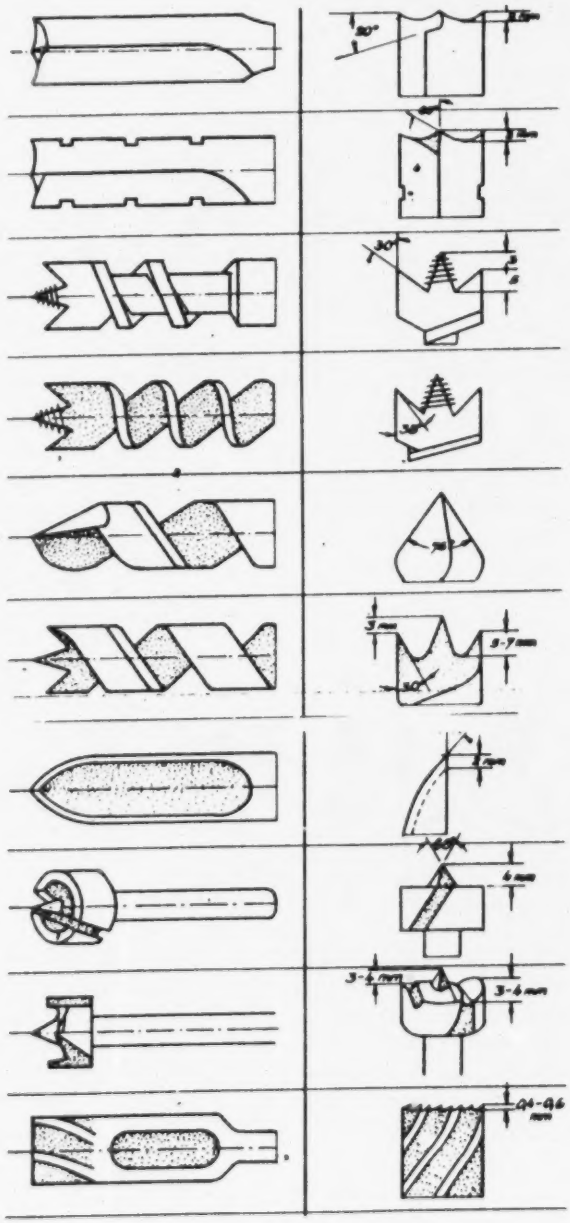
For hardwood and boards manual boring (manual dowelling)

For hardwood machine boring; bore-holes have a small diameter and depth

Mortising tool for knots

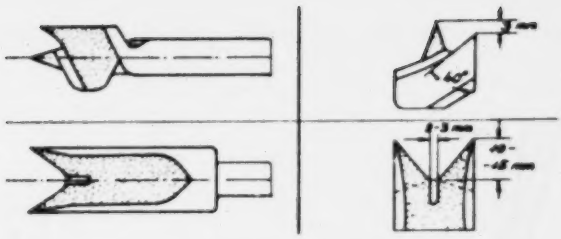
Borer for knots and holes needed for fittings

Mortising tool for plugging



Borer for manual insertion of fittings (bore-holes for locks)

Boring tool used in an automatic suspended borer

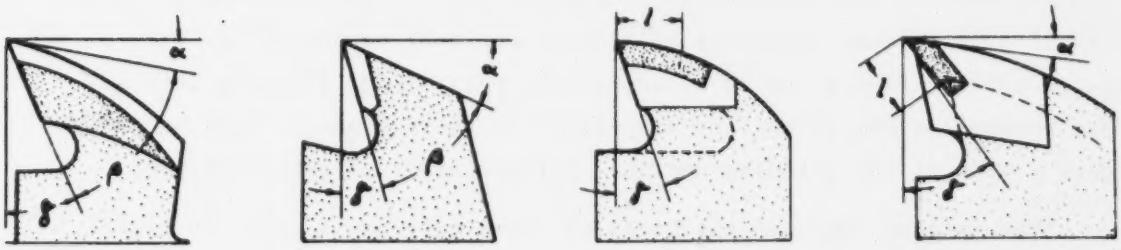


9. SHARPENING OF CUTTERS FOR WOOD AND WOOD-BASED MATERIALS

Cutters and borers are sharpened exclusively by sharpening and grinding machines, which assures that all cutting tips are equally distant from the centre-line of the tool. All cutting edges must be sharpened at the same angle. Mechanical sharpening of cutters and borers also assures a balanced tool since the chipped-off surface is equal in all cutting edges. The geometry of cutting edges is often determined by manufacturers of tools, but more often even by the users themselves. It is, therefore, indispensable to know under what conditions individual species and different wood-based materials should be cut. It is also necessary to know when to use cutting tools made of alloy steel and when those entirely made of Widia the strength of which is that of carbide boring tools - or when cutting tools should be used that are tipped with Widia plaquettes.

The sharpening of Widia-plated tools has already been described; sharpening rates and check-ups of tools may considerably reduce maintenance cost and boost the profitability of the tools.

C'assical shapes of cutting edges in cutting tools.



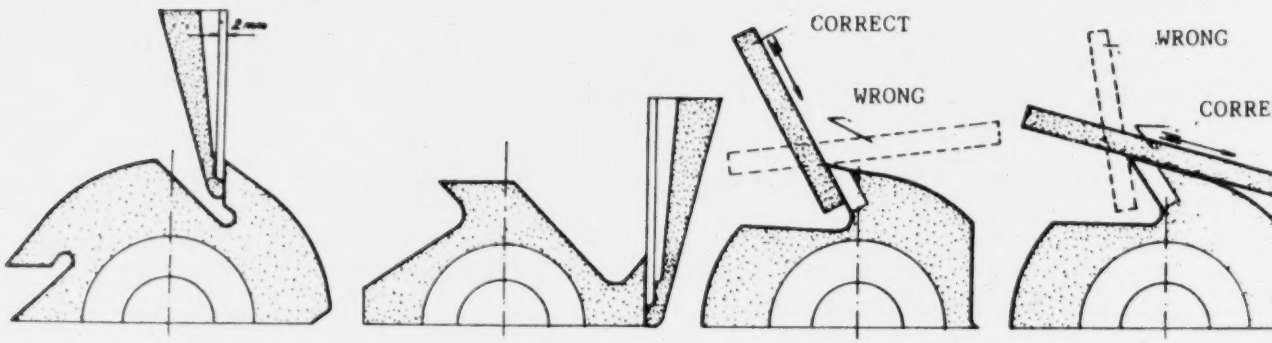
Solid (steel) cutter tooth.

Radially inserted tungsten carbide-tips.

Tangentially inserted tungsten carbide-tips.

Combined radially and tangentially inserted tungsten carbide-tips.

Fundamental cutting modes for cutting tools



Front bevel sharpening. | Back bevel sharpening. | Front bevel honing. | Back bevel honing.

10. KNIVES FOR THE CUTTING AND PEELING OF VENEER

A maintenance programme for knives used in the cutting and peeling of veneer includes the following stages: cleaning, sharpening and honing. Prior to sharpening veneer knives must be thoroughly cleaned with a solvent to remove stains on knives; often a cloth soaked in the solvent (a solution of oil and machine oil) will do.

The sharpening of veneer knives is done by a machine to which a tub is attached. The knife is clamped to machine gripping heads, either by means of screws or magnets. A sharpening tool moves along the knife; the tool is made up of segments or a large-diameter concave grinding wheel. A coolant must be fed permanently to the sharpened surface during grinding, and it will prevent excessive heating of the cutting edges. In view of the large coolant flow a tub is a constituent part of the grinding machine. Two hundred litres of coolant are stored in the tub and it must be changed once a week if the grinding machine operates under normal conditions.

The cutting angle of the knife is relatively small, i.e. 18 to 22°. In view of such a small angle a chipped surface develops during sharpening, which cannot be renewed automatically. Therefore manual devices are used

for this purpose, i.e. the best natural grinding stones. With such stones that are rinsed in caustic liquids the cutting edges of the knives can be formed in the best way.

11. CONCLUSIONS

Adequate maintenance of cutting tools used in a woodworking plant can be achieved only when a well-equipped sharpening and grinding workshop is available. It must be located in such a manner that the handling of the tools in the entire plant is as optimal and rational as possible.

Attention should be paid, furthermore, to machines and equipment of the workshop. It is recommended to use sharpening and grinding machines adjusted to specific tools and devices, and the sharpening programme should be changed as rarely as possible.

Qualifications and skills of workers employed in a sharpening and grinding workshop are extremely significant for a proper maintenance of cutting tools and devices, as well as viability of woodworking plants. The workers of such a workshop therefore must be highly skilled, and given access to further on-the-job training programmes.

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PARTICLE BOARD - TECHNOLOGICAL PROCESS AND SOME PROPERTIES*

Prepared by

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1. INTRODUCTION

A brief chronology of the evolution of considerations and practical approaches to particle board will be outlined in this introduction. The first initial ideas related to particle board go back to the end of the last century; to be more particular to the year 1887 when Ernst Hubbard suggested the production of boards made of waste materials in one of his articles published in Germany. Efforts were pursued later along the same lines in the United States (Watson, 1905) and Germany (Beckmann, 1918 and Freudenberg, 1926). In addition to a number of other advocates of this idea, two Americans (Carson, 1932 and Nevin, 1933) continued with the efforts to put it into practice. Loetcher of the United States was the first, in 1935, to even embark upon production in a prototype plant. In Switzerland, Pfhol and Chappius obtained patent rights in this field, and the former is considered the author of the widely known European patent covering the manufacturing of particle board. The technical options related to the manufacturing of particle board were put into practice primarily due to the economic crisis in 1940 and 1941, obviously with a number of risks involved in the project. The first plant, although rather small, went into operation in 1941 at Trofit Werke in Bremen, Germany. Inadequate and too expensive synthetic adhesives are considered to have been a major obstacle to practical production in the years before 1941. Fred Fahrni has considerably improved the process of industrial production of particle board and, therefore, has been considered one of the leading pioneers in this field. After World War II, activities related to the development of particle board were significantly intensified, particularly within the framework of the Institute for Wood Studies in Braunschweig (Dr. W. Klauditz), as well as by manufacturers of adhesives and woodworking machines. By 1949 production of good urea-formaldehyde adhesives had been achieved, and simultaneously a number of special machines required in individual stages of particle board production were also developed.

The period after 1950 is characterized by a gradual expansion in the production of particle board, based on experiences gained through trial runs, new marketing strategies and development of new manufacturing facilities in the years 1941-1950. The first production of particle board in Yugoslavia goes back to 1961; 13 small-scale plants with an annual capacity of 6,000 tons had been erected by the year 1964. Modern, technologically adequate and economically viable production of particle board in Yugoslavia, however, began only after 1970; by 1976 4 up-to-date particle board plants had been established in Slovenia in the following enterprises: GLIN in Nazarje, LESNA in Slovenj Gradec, BREST in Cerknica and MEBLO in Nova Gorica.

The following table gives comparative data for sales of particle board and fibreboard on the international market (in 000 m^3):

Region	Particle board[1/]		Fibreboard[1/]		Plywood[1/]	
	1981	1982	1981	1982	1981	1982
Europe	23,569	22,922	4,066	4,225	3,444	3,286
Yugoslavia	789	830	114	110	153	152
Soviet Union[2/]	5,000	5,300	-	-	2,000	2,000
Canada	715	600	740	560	2,086	1,700
U.S.A.	6,100	5,000	4,900	4,600	14,800	14,300

[1/] Estimates are given for 1982 (source: ECE, Geneva, 1982).

[2/] Fibreboard sales figures were not available for the Soviet Union.

For the sake of comparison it may be mentioned also that the world output of plywood exceeds that of fibreboard.

This paper outlines the specific technological process applied in the LESNA, Slovenj Gradec, particle board plant, as well as some characteristic features of this type of production and of particle board in general. Problems, however, related to this topic are certainly much more extensive and numerous than may be considered by a paper of this scope.

2. SOME PROPERTIES AND CHARACTERISTICS OF PARTICLE BOARD

Before proceeding with this paper it is necessary to define particle board. According to T. Maloney the definition of a particle board is: "A generic term for a panel manufactured from lignocellulosic materials (usually wood), primarily in the form of discrete pieces or particles, as distinguished from fibres, combined with a synthetic resin or other suitable binder and bonded together under heat and pressure in a hot press by a process in which the entire inter-particle bond is created by the added binder, and to which other materials may have been added during manufacture to improve certain properties. Particle boards are further defined by the method of pressing. When the pressure is applied in the direction perpendicular to the faces, as in a conventional multiplaten hot press, they are defined as flat-platen pressed; and when the applied pressure is parallel to the faces, they are defined as extruded".

The ISO (International Organization for Standardization) definition is as follows: "Panel material manufactured under pressure essentially from particles of wood and/or other ligno-cellulosic fibrous materials (for example wood chips, sawdust, flax shives, etc.) with or without the addition of an adhesive, hydraulic binders being excluded".

It is particularly in highly developed and industrialized countries that properties and characteristics are specified clearly for individual types of products. This field is regulated in national standards elaborated within separate committees or standardization unions. Some of the most known standards that spell out technical regulations covering particle board are:

DIN	68 763	Deutsche Industrie Normen
DIN	68 761, Teil 1	
DIN	68 761, Teil 4	
BS	5 669	British Standard
ASTM	D - 1037	American Society for Testing and Materials
ASTM	D - 1554	
ISO	820	International Organization for Standardization
ISO	821	

ISO	822	International Organization for Standardization
ISO	823	
ISO	DIS 4025	
ISO	P 5606	

In order to facilitate the solution of problems within the international framework, the ISO has embarked upon the elaboration of international standards for particle board. In Yugoslavia properties of particle board are stipulated by the national standard JUS:

JUS	D.C5.030
JUS	D.C5.031
JUS	C.C5.032

It is necessary to stress here the close correlation between standardization efforts, on the one hand, and the technological progress made in individual countries on the other. Particle board standards, for example, in West Germany are thoroughly developed as they have been permanently updated and thus followed the technological progress in this field. The following chapters of the paper will outline some of the most significant mechanical properties of particle board spelled out in the DIN standards. All data and figures apply to particle board used in the furniture industry, and hence reflect the level of progress and requirements of this industry. Properties required for individual types of particle board are closely related to the purpose for which they are used. The standards, for example, specify the properties of particle board used in building and construction. The vast majority of the standards stipulate properties of individual particle board thickness classes. Let us examine some particle board properties required in furniture industries; this type of particle board is defined in the standards as general purpose particle board:

Thick class	Bending strength	Tensile strength	Thickness swelling	Moisture content
mm	N/mm2	N/mm2	%	%
DIN 13-20	16	0.35	8	5 - 11
JUS 14-19	18	0.41	8	9 - 3

Let us here underline the fact that most national standards, including DIN, stipulate minimum values; the JUS, however, contains three quality classes of particle board (Extra, I, II) and the above JUS figures only apply to top quality particle board. Individual standards differentiate among varying thickness classes; this paper covers the thickness class generally applied in the furniture industries.

The Yugoslav standard for general purpose particle board (JUS D.Ç5.031) contains three thickness classes; in addition to that specified in the table on page 4 there is one class up to 14 mm and one above 19 mm, whereby thickness intervals are always 1 mm.

Most national standards classify particle board on the basis of the following criteria:

Manufacturing process:	Flat pressed
	Extruded
Structure:	One-layer
	Three-layer
	Multi-layer
	Graded layer
Face surface:	Pressed
	Sanded
	Coated
	Veneered
Density:	Low-density
	Medium-density
	High-density
Particle board type:	In terms of applied adhesive
	In terms of purpose

The following basic standards cover the properties of unprocessed particle board in West Germany and Yugoslavia:

Standard / Purpose of use	DIN	JUS
For general purposes	68 761	D.C5.031
For building	68 763	D.C5.032

The table below gives comparisons among indivudual types of particle board specified in the above-mentioned standards:

Standard / Purpose of use	DIN	JUS
For general purposes	V 20	TP 20
For building	V 100	TP 100
	V 100 G[1/]	TP 100 G[1/]

[1/] Protection against Basidiomyceten.

The next table indicates adhesives used according to DIN standards:

Resin / Type of board	UF	PF, P PR,	UFM[1/]
V 20	X	-	-
V 100	-	X	X
V 100 G	-	X	X

UF	Urea-formaldehyde resin
PF	Phenol-formaldehyde resin
P	Phenol resin
PR	Phenol-resorcinol resin
UFM = UF	- Melamine resin

[1/] Subject to special approval of an authorized institution.

[2/] Additional protection against Basidiomyceten.

Durability and resistance of boards to climatic conditions, i.e. micro climate, are defined in JUS D.C5.032 (Particle board with horizontal particle distribution for building purposes):

TP 20	Boards resistant when used indoors, not resistant to atmospheric climatic conditions
TP 100	Boards resistant to high relative air humidity, with limited resistance to atmospheric climatic conditions
TP 100 G	Boards resistant to high relative air humidity, with limited resistance to atmospheric climatic conditions; additionally protected with a fungicide.

3. DESCRIPTION OF THE TECHNOLOGICAL PROCESS

(a) Storage of wood-based raw materials

About 140,000 m^3 of wood-based raw materials of varying assortments and species are needed for the existing maximum annual outputof 90,000 m^3 of particle board. The structure of the wood-based raw materials required is as follows:

Coniferous species	65 %
Broadleaved species	35 %

The ratio of woodworking waste and shavings to round logs is 60 : 40, and the structure of the 60 % of woodworking waste is as follows:

Chips	30 %
Sawdust	25 %
Off-cuts from sawmills	45 %

Obviously the above ratios may change to a certain extent from one year to the other. The average monthly stocks of wood-based raw materials are two months' requirements. The plant has 10,000 m^2 of asphalt-covered storage space, and slightly more than 10,000 m^2 of storage space on non-surfaced soil. Some raw materials are transported to the plant by rail, but the majority reach it by road (trucks and lorries).

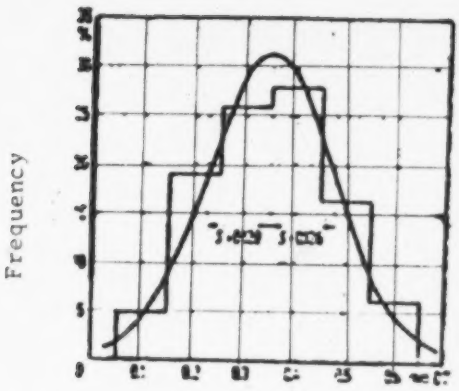
(b) Particle preparation

Particle preparation consists primarily of the manufacturing, classification and drying of particles. Depending on the structure of wood-based raw materials, different flakers are utilized to process particles. Two

U - 74 drum flakers manufactured by the HOMBAK company are used for long round logs and partially for scantling and slabs, two Pallmann ring flakers are used for chips, and a chipper manufactured by Kloeckner is used for the preparation of chips from sawmills' scantlings.

The refining of surface layer particles precedes drying and follows pre-drying; the flaking stage is accomplished in ring refiners manufactured by the ALPINE Company. The preparation of surface layer particles is separated from the preparation of core layer particles. The general feature of the technological process used in this particular plant for three-layer particle board is the separate preparation of surface and core layers that precedes the particle spreading stage. Sawdust is classified mechanically prior to storage in a silo and drying. Particles are stored in separate silos according to their varying properties, and the quantitative dosing required for each individual layer is monitored and adjusted to the specific requirements for each board thickness. The next stage is drying. Prior to drying the moisture content of particles varies: in summer it is lower than in winter, and may, in extreme cases, be as much as 130 per cent. Surface layer particles must be dried to about 3 per cent moisture content, and core layer particles to around 2 per cent. The drying of surface layer particles goes through two stages: during pre-drying the particles are dried to 35 - 45 per cent moisture; during the consequent flaking in the ALPINE ring refiners and the final drying, the target moisture content is reached. The drying itself occurs in tube dryers manufactured by Buettner with continuous fresh air operation. Once dried, the particles undergo air classification in classifying machines manufactured by Keller; the particle air separation is applied separately for surface and core layers. Once this stage is over the particles are transported to dry-particle silos.

The quality and thickness of surface and core layers' particles vary. The envisaged thickness of surface layer particles is 0.20 - 0.30 mm, and that of core layer particles ranges between 0.40 to 0.50 mm. It is desirable that the distribution curve be as narrow and sharp as possible, i.e. tha the distribution be as even as possible.



This is an example of normal distribution of particles; in practice the curve may be lower or shifted more to the right or to the left in its own axis, i.e. asymmetrical.

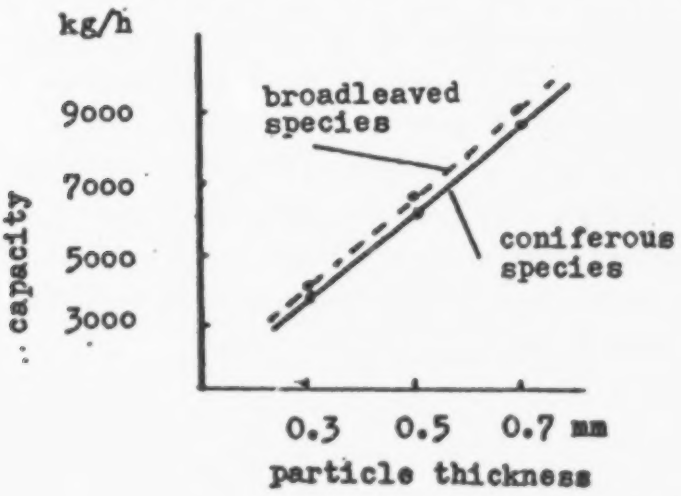
The quality and form of the particles obviously can also be influenced by other factors, such as:

- The type of wood-based raw material (form and species of wood)
- The moisture content of the wood
- The setting of the woodworking machines

The flaker's capacity, on the other hand, will depend also on a number of factors:

- The type of wood-based raw material (round logs or industrial wood residues)
- Particles' thickness
- The wood species (coniferous, broadleaved)
- The moisture content of the wood.

The impact of wood species and particles' thickness may be illustrated by the curve of the flaker's capacity in hours, shown below:

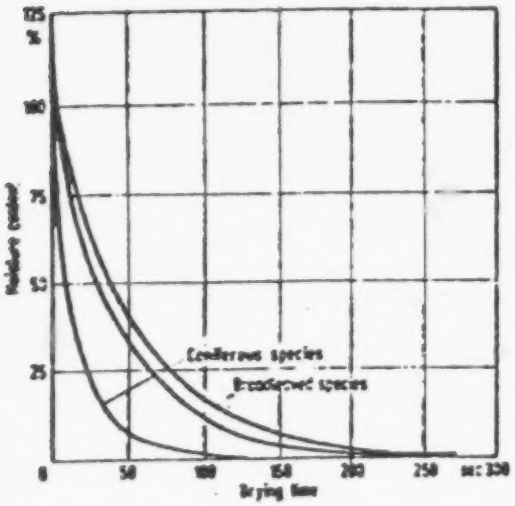


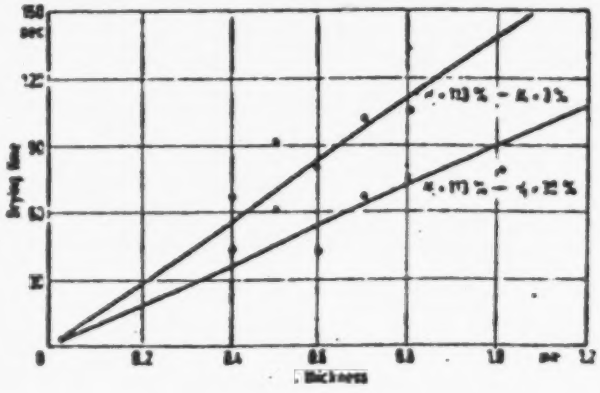
Ring flaker capacity for Type KHZ-14, KLOECKNER Co.

The type of particles used obviously influences the drying process itself which, generally, depends on the following properties:

- The moisture of the particles
- The thickness of the particles
- The species of wood

The moisture content, in particular, exudes correlation with wood species, and together with the particles' thickness it influences the time and quality of drying. The following two diagrams illustrate drying time and quality:

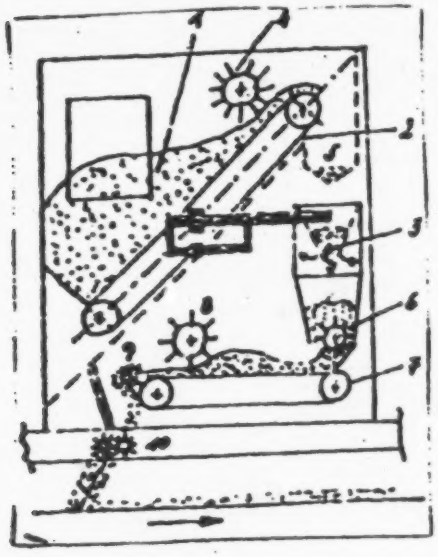




(c) Gluing and spreading of particles

The particles are transported from both the dry particles silos for surface and core layers to weighing scales, a flattening hopper, and gluing machines. The gluing is performed in two KTT-350 gluing machines manufactured by DRAIS; one of them is used for the surface and the other for the core layers. The nozzles for glue distribution are located along the axis of the gluing machine; the gluing process thus implies a centrifugal motion of the particles from the axis towards the outer casing of the gluing machine. The casing itself is cooled by water. The particles travel in circles from the flattening zone through the gluing zone towards the zone of subsequent mixing. The

gluing is based on the use of a glue mix, composed of urea-formaldehyde adhesive, a hardening agent, a paraffin emulsion and water. The mix is prepared separately for the surface layer and the core layer. The hardening agent is used to control and regulate the timing of the glue-binding process that follows the previously described stages and only takes place in the hot-pressing stage. The surface layer moisture content ranges from 11 to 12 per cent, and that of the core layer between 8 and 9 per cent. The glue mix is usually prepared in a special room. Once the particles are all covered by glue they travel from the gluing machines to spreading machines manufactured by WUERTEX; here two spreading machines are utilized for the spreading process for the surface layer, and another two stations for the core layer.



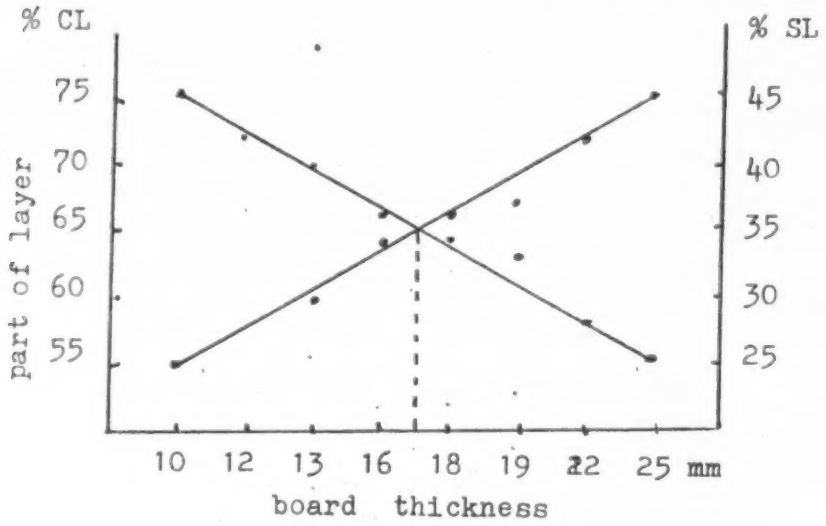
1. Loading hopper
2. 7. Infeed and outfeed conveyors
3. Weighing hopper
4. 8. Kick-back rollers
9. Outfeed brush roller
10. Needle roller

The above figure illustrates the spreading method used in our specific spreading machines. A combination of gravimetric and volumetric spreading is applied in this specific type of mat forming. The particles are spread on the forming belt that is moving to the press.

A metal detector and a pre-press are located next to spreading machines. A continuous cold pre-pressing process is the next stage, where a pressure of 0.30 - 0.40 N/mm^2 is used in the pre-pressing stage.

The pre-pressing itself boosts the strength and homogeneity of the chip mat, which is of paramount importance in view of the risk that the mat structure may be impaired during the transportation of the mat along different conveyors. This problem is much less significant in the technological processes that imply the use of special support plates or wire screens.

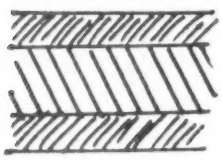
The particle size of the surface layer is smaller than that of the core layer, and the quantity ratio between the surface layer and core layer particles depends on the board thickness desired. See the diagram below:



CL = Core Layer SL = Surface Layer

The diagram indicates a specific feature of the specific type of technology used in our plant, i.e. that the share of the core layer grows with the increase in board thickness, and vice versa.

An example of the surface layer/core layer ratio for a 17 mm thick particle board 65 / 35 per cent is shown below:



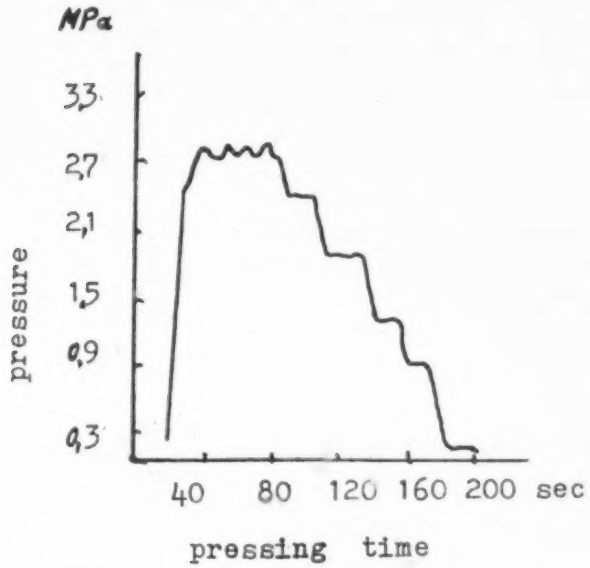
SL 17.5 %

CL 65 %

SL 17.5 %

(d) Pressing of the particle mat

From a forming belt the mat travels to an accelerating belt and a feeding belt towards the press. A special tray belt press loader, located prior to the press, is now loaded with mats; this discharging service is used to feed the seven-day light press. Pressing temperatures range from 150° C to 180° C, depending on the board thickness. The press manufacturer is SIEMPELKAMP.



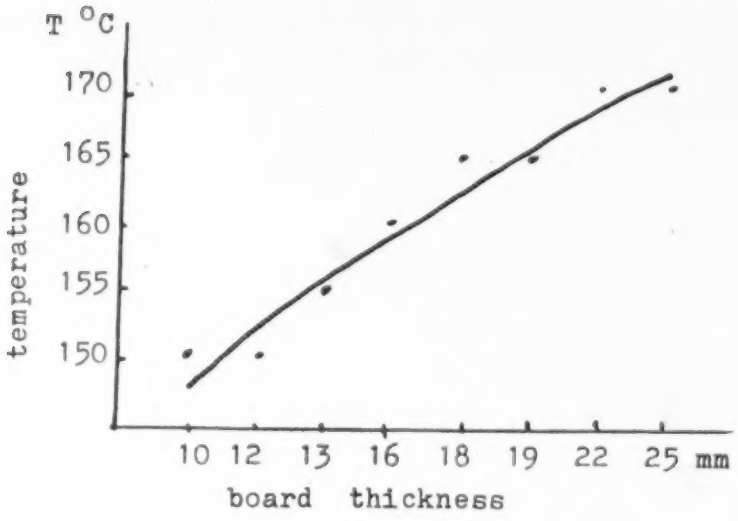
Analyzing the above diagram the following stages may be observed:

- Press closing time
- Chip consolidating time
- Vapour-removal time

In functional terms, on the other hand, the following procedures are involved:

- Secondary routines (press loading and discharging)
- Press closing
- Maintenance of nominal board thickness

The diagram below shows pressing temperature and its dependence on particle board thickness:



The technology described here involves water-heating of the press. There are obviously other systems in which the heating medium could be thermal oil and where temperatures considerably above 200° C can be achieved. That high temperature is certainly inconceivable in water-heating systems. In addition to adequate pressure the temperature of at least 103° C in the board core is another prerequisite of a good pressing procedure. The entire technological process and the glue polymerization depend on the above temperature. The specific pressing pressure is 2.8 N/mm^2. Pressing time primarily depends on:

- Pressing temperature
- Pressure
- Mat thickness

Pressing time is expressed by the pressing factor (f_p) that is determined by the following ratio:

$$f_p = \frac{t_p}{a_b} = \frac{t_p}{a_n + 1.5} \quad \text{(min/mm)}$$

f_p = pressing factor

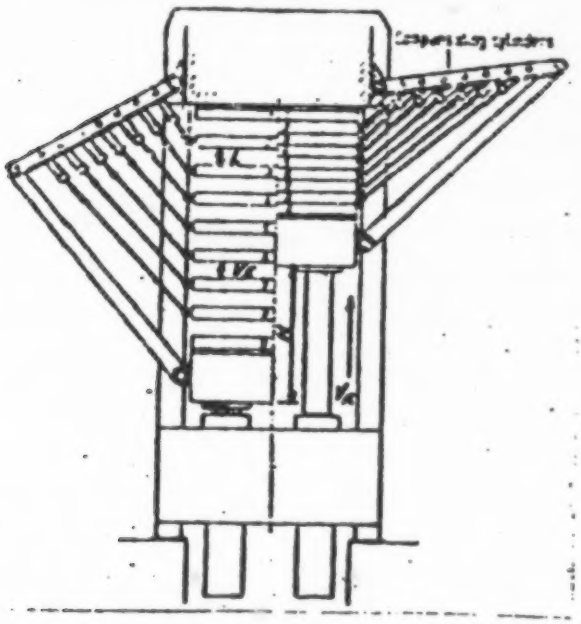
t_p = pressing time

a_b = gross board thickness

a_n = net board thickness

When the operation time is longer (in difficult working conditions during winter) the pressing factor for a 16 mm thick board amounts to f = 0.23 min/mm. In normal operating conditions the pressing factor may be reduced to 0.20 min/mm.

Press closing is simultaneous, i.e. all the mats in the press are in contact with heating plates simultaneously. The figure below illustrates the press closing cycle:



L = light opening (mm)

V_e = light closing speed (mm/sec)

H = maximum possible press lift

$$V_E = \frac{V_k}{n} \; ; \qquad ts = \frac{n \cdot L}{V_k} = \frac{H}{V_k}$$

V_k = cylinder speed (mm/sec)

n = number of openings

t_s = closing time of the press without mat (sec)

Particle board strength in general, and bending and tensile strength, in particular, depend on press closing time. Boards produced in an operation that involves rapid press closing are characterized by:

- Good bending strength
- Normal tensile strength

The density profile of such a board looks like the graph on page 17.

If the press closing time is longer, the tensile strength will increase and bending strength will be normal. The pressing process can be monitored freely; hence the particle board properties that certainly depend on technical possibilities, too.

Special distance bars can be used to regulate the board's thickness in the press itself; the distance bars are inserted into the press and correspond to varying board thicknesses. Electronic monitoring of nominal board thicknesses is also possible; here no distance bars are used and only the four press edges are monitored.

Once the pressing cycle is finished, the boards leave the press and have a moisture content of about 7 per cent and a termperature of almost 100° C. The cooling stage begins immediately after pressing. The boards are loaded onto a special turning device and cool down to some 60° - 70° C. The next is the curing stage during which the boards are stored for three to seven days. The main characteristics of the curing process are:

- Equalization of moisture content inside the boards
- Final binding, i.e. glue condensing, stage
- Equalization of intrinsic tensions

(d) Sanding and cutting to size

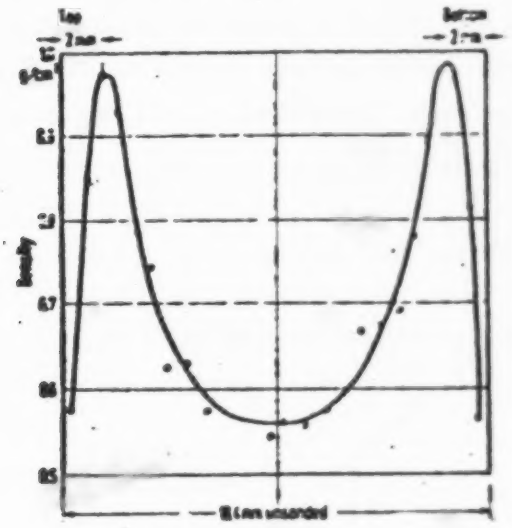
Once the curing stage is over the boards are sanded on a wide-belt sanding machine manufactured by BISON-BAEHRE; the machine has six heads and three motors. In the first stage the board thickness is balanced and in the next two stages the boards are fine-sanded.

The feed speed is 10 to 20 m/min and it depends on:

- Board thickness
- Thickness tolerance

- Surface layer density
- Further use of the boards (purpose)

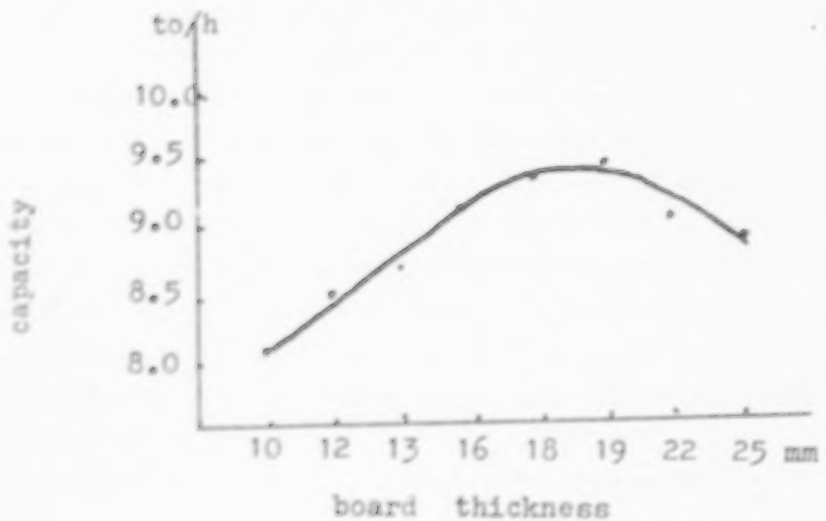
The boards that are to be improved at later stages of the process and whose density ranges between 900 and 1,000 kg/m^3 are sanded at a low feed speed (10 - 15 m/min). The normal boards, aimed for further processing and used in furniture manufacturing, are sanded using a combination of sanding papers, the grain size of which is 40 to 80. The sandind is then followed by longitudinal squaring, transverse squaring and, if necessary, the boards are then cut into two or more pieces. The boards are then inspected and graded on special tables; the grading is based on mechanical properties determined by laboratory testing, as well as visual determination of board surface quality. Tolerated thickness variations after sanding depend on the boards' thickness; variations tolerated for a particle board with a thickness up to 20 mm is ± 0.30 mm, and for thicknesses above 20 mm it is ± 0.40 mm. When discussing the sanding procedure the following significant element for the determination of some particle board properties must be understood. It is the cross-section density profile of a board. A typical profile of this type is shown below:



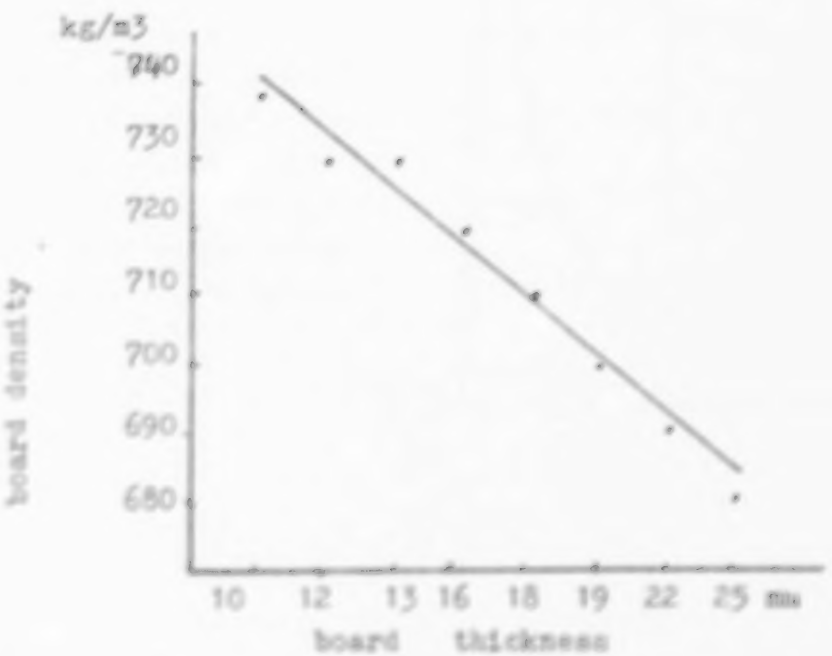
In this connexion we must point out the need to remove (by sanding) a portion of surface layer which is immediately followed by a layer with high density. In this manner desired surface quality may be achieved.

4. SOME CHARACTERISTIC FEATURES OF THE PRODUCTION PROCESS

The basic net size of the boards, in the case of the factory visited, is 2,050 x 5,500 mm, and their thickness ranges from 6 to 28 mm. The plant's capacity is correlated to board thickness and indicated in the diagram below:



Like capacity per hour, the board density is also correlated to board thickness:



The diagrams indicate that board density declines with the increase in board thickness. The plant is in operation 355 working days a year, and it operates in three shifts, with four teams. Major repair and reconstruction or overhaul operations are planned on an annual basis.

The plant employs a total of 230 persons. Some 40 per cent of all boards are further improved on two SIEMPELKAMP KT lines (using the short pressing cycle procedure). The annual output has recently approached 90,000 m^3 of which some 2.5 million m^2 are surfaced with melamine resin impregnated paper. Sixteen mm boards account for some 60 per cent of the entire output and this thickness is used almost exclusively for surface improved boards.

The consumption of the most significant raw materials and power per unit of product in this plant meets the following standards:

Wood-based raw materials	1.55 m^3/m^3
Adhesive	100 kg/m^3
Power	160 kwh/m^3
Fuel oil	65 kg/m^3

The above power figure does not comprise the power used for both KT lines for the surfacing of particle board, nor the power obtained by sanding dust used as fuel in the boiler room. The figure, however, covers the power required for technological steam and to fire the drying machines.

All other costs are relatively small, and the above standard consumption of basic raw materials and power accounts for two-thirds of all costs incurred. The salaries, for example, only represent about 6 per cent of the plant's total expenditure. In addition to the above variable costs, annuities and interests, both in dinars and hard currency, account for a major part of the fixed costs.

5. QUALITY CONTROL

There is a well-equipped laboratory and qualified experts who closely follow the technological process in all of its stages. Every day quality control of the input of raw materials is undertaken; in the production

process quality control follows individual production stages, and end products are submitted to thorough scrutiny as well. In terms of organ-organization, the quality control department is closely related to the technology department.

The quality control of the following raw materials is a routine operation in the plant:

- All types of wood (shavings, chips, sawdust)
- Adhesive (specific weight, pH, dry substance content, gelation time, viscosity)
- Paraffin (melting point, purity)
- Paper used for surface improvement of boards' moisture content, resin content)

The most significant quality controls during individual stages are:

- Moisture of particles (dry and wet particles)
- Structure and form of particles
- Gluing mix (dry substance, gelation time, viscosity)
- Gluing of particles
- Boiler water (pH, hardness, etc.)

Polluted water is also analysed (e.g. dry substance content, pH, formaldehyde and oxygen content, temperature).

The following properties of the particle boards are controlled:

- Moisture content of thechip mat
- Bending strength
- Tensile strength
- Swelling
- Board thickness
- Density

The above quality control routines and properties are those for the TP 20 boards used for general purposes.

The boards, as a rule, should be monitored in compliance with the relevant standards. The JUS D.C5.031 applies to boards used for general purposes, and the JUS D.C5.032 applies to boards used for construction.

No Yugoslav standard is available for improved boards that have not been dealt with in this paper. Therefore the quality control of the end product is, in this case, based on the American NEMA* LD 1-2.01, LD 1-2.02, LD 1-2.05 and the German DIN 68 765 standards. The properties of the boards that are spelled out in the basic standards, however, may also be determined on t ∠ basis of the standards required by specific methods.

The JUS requires the testing of one board of each thickness class per day. In practical terms one board is tested in each shift. The quality control results are processed statistically by calculating the mean value $\bar{x}$ and the standard deviation . The results are then recorded on special control cards. The calculation method itself is laid down in a special standard.

Once a year boards are tested by an authorized institute that eventually issues the certificate on their properties. One board in each thickness class is tested in this framework.

Occasionally the free formaldehyde content in the boards is also tested by the plant. For this purpose a special perforator method is used as stipulated by FESYP.** Yugoslav standards have not so far required the checking of the free formaldehyde content. Hence no maximum values that may be contained by individual board types are prescribed in our standards. Speaking about free formaldehyde, the German standard DIN 68 761 (part one) is applied conditionally; i.e. it is still in a testing stage. It applies to general purpose boards and its paragraph 3.4 that deals with the free formaldehyde emission requires at least the E3 emission class for the boards in question. For the sake of explanation of this problem let us emphasize that guidelines have been elaborated for the territory of the Federal Republic of Germany that cover classification of boards in terms of free formaldehyde emission. The following classification of emission classes is contained in table 1 of the guidelines:

---

* National Electrical Manufacturers' Association, 155 East 44th St., New York 10017, U.S.A.

** European Federation of Particle Board Manufacturers' Associations, Wilhelmstrasse 35, 63 Giessen, F.R.G.

Emission class	Emission value in ppm HCHO	Perforator value in mg HCHO/100 g of an absolutely dry board
E1	0.1	10
E2	0.1 to 1.0	10 to 30
E3	1.0 to 2.3	30 to 60

Emission of free formaldehyde is indeed a problem the solution of which can no longer be postponed, even in Yugoslavia. In this field efforts made by both particle board manufacturers and the manufacturers of adhesives to reduce the emission can already be noticed and observed.

6. CONCLUSIONS

This paper deals with some properties and characteristic features of particle board, as well as the technological process of its manufacture. The properties and required quality of the boards have been related to the technical legislation and standards available. The paper briefly outlines the technological process used in a specific plant at this moment. The author attempts to single out those properties that are common to all particle board manufacturers, particularly those of three-layer flat pressed particle boards that are based on a belt-transportation of the chip mat to the press.

The plant described in this paper manufactures the largest assortment and range of boards in Yugoslavia in terms of the sorts and types of particle board. Let us enumerate them once again:

TP 20	Boards used for general purposes
TP 100	Boards for use in construction and building
TP 100 G	Boards additionally protected against fungi
OP	Surface improved boards

The TP 100 G board was produced industrially for the first time in September 1983. The plant also manufactures a board resistant to termites (TP 100 GT is the internal code number for this board),

which is particularly suitable for use in tropical and subtropical climatic conditions, characterized by the problem of termites, and where inadequate boards may have disastrous consequences.

The paper does not cover the technological process used in the manufacturing of surface improved boards that are also produced in the plant in question.

Some diagrams have been used also for outlining the specific technological process and properties of particle board; they either refer directly to the technological process described or can be found in literature.

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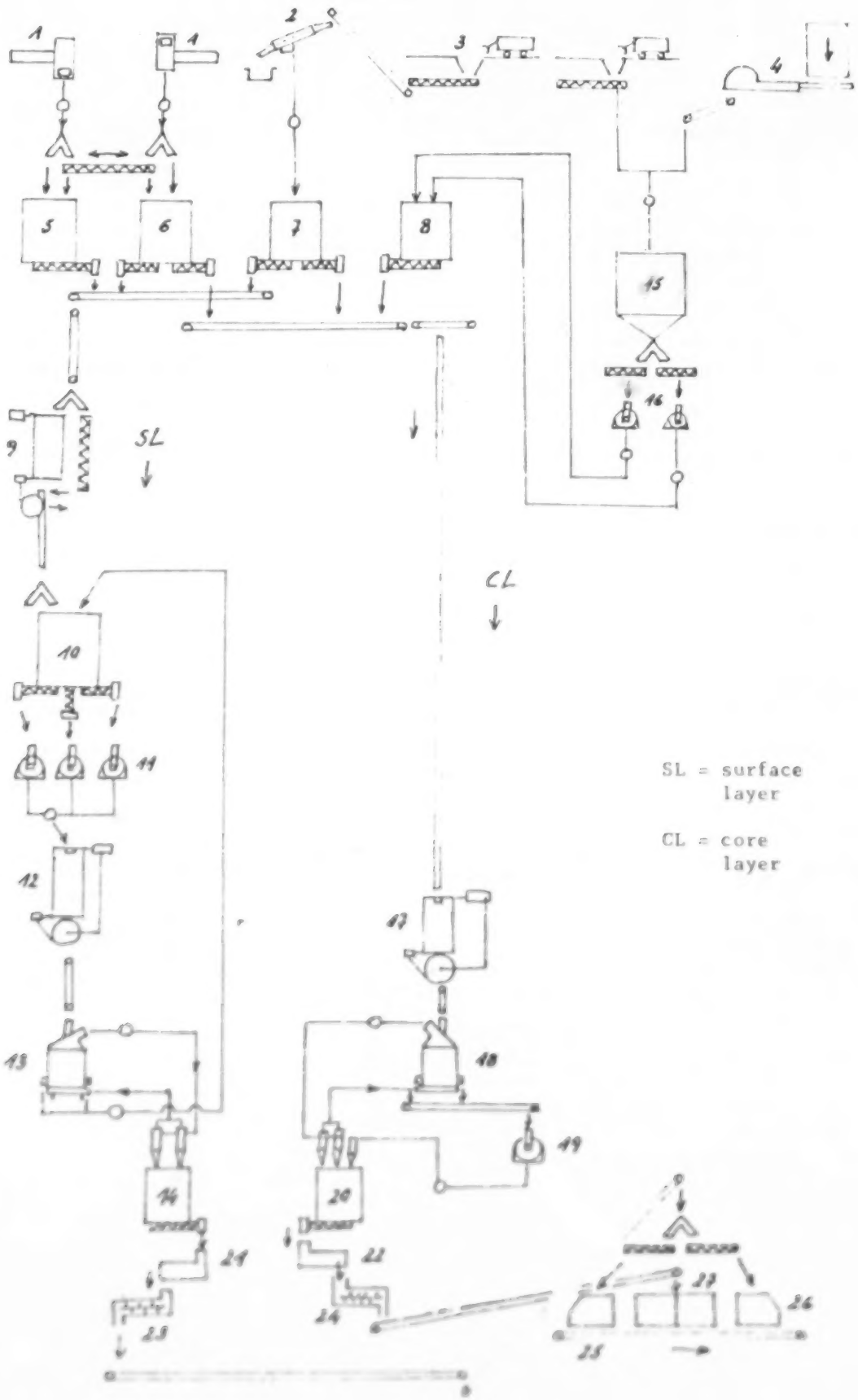
5. Deppe, H. J. : Tuscherbuch der Spanplattentechnik, DRW-Verlag, Stuttgart, 1977.

ANNEX

TECHNOLOGICAL PROCESS FOR PARTICLE BOARD PRODUCTION

LAYOUT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SL
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CL
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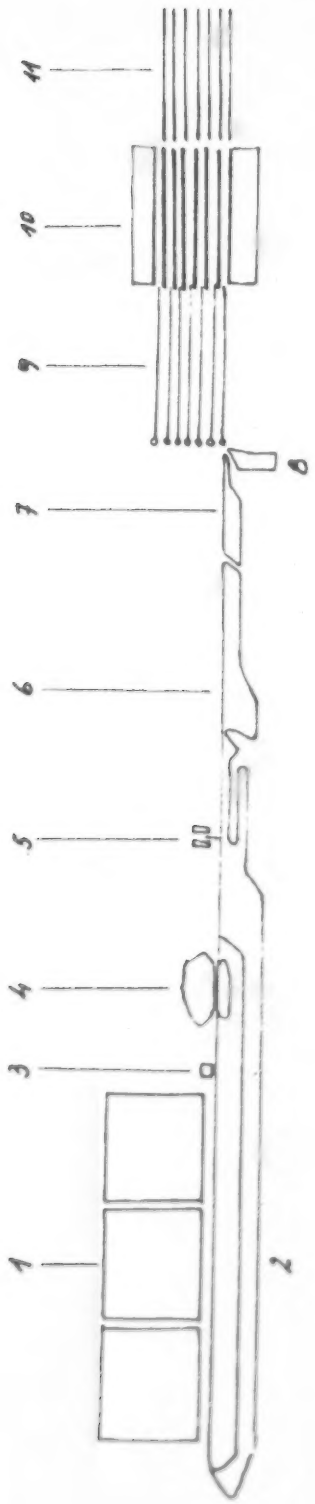
23
24
25
26
SL = surface layer
CL = core layer

1. Flakers
2. Vibrating screen
3. Sawdust
4. Chipper
5. Coniferous wood)
6. Broadleaved wood)
7. Coniferous sawdust) Wet particle silo
8. Ring flakers particles)
9. Pre-dryer
10. Dosing silo
11. Ring refiners
12. Dryer
13. Air classifier
14. Dry particles dosing silo
15. Chips dosing silo
16. Ring flakers
17. Dryer
18. Air classifier
19. Ring refiner
20. Dry particles dosing silo
21, 22. Balance silo
23, 24. Gluing machine
25, 26. Surface layer spreading machine
27. Core layer spreading machine

CONTINUOUS FORMING BELT SYSTEM



1. Spreading (forming) machine
2. Forming belt
3. Metal detector
4. Continuous pre-press
5. Mat-separating device
6. Acceleration station
7. Feeding station
8. Reject mat hopper
9. Tray belt press loader
10. Hot press
11. Discharging device